

# THE SIPUNCULIDS OF THE EASTERN COAST OF NORTH AMERICA.

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## INTRODUCTION.

The large collection of sipunculids from off the eastern coast of North America that has been accumulating in the United States National Museum during the past 40 years, chiefly through the explorations of the United States Fish Commission and the present Bureau of Fisheries, has hitherto not been studied, and almost nothing has been known of the rich sipunculid fauna of the western part of the Atlantic.

The genus *Phascolosoma* has been thought to be represented in this region by three species only: *Phascolosoma gouldii*, a littoral form not uncommon in New England, *Ph. eremita* (= *boreale*), found in waters of medium depth off the New England coast, and *Ph. flagriferum*, an abyssal species. Eight others are now, from the study of this material, to be added to the list of Phascolosomas found off the eastern coast of North America, two of them being new species and another, *Ph. verrillii*, here for the first time fully described. The five remaining species (*margaritaceum*, *cylindratum*, *procerum*, *sabellarix*, and *improvisum*) have not been recognized as belonging to the American fauna. *Ph. flagriferum*, mentioned above, originally described from a specimen taken by the *Challenger* from the deep sea eastward from Virginia, is again recorded as having been dredged by the U. S. Fisheries steamer *Albatross* in the same latitude, but nearer the Virginian coast.

The genus *Phascolion* is represented in the United States National Museum by an abundance of material from all parts of the eastern coast, exhibiting such a wide range of variation that the writer was at first inclined to describe several species. Prolonged and thorough study of this material, however, has led to the conclusion that all these variations should be referred to the single cosmopolitan species, *Phascolion strombi* (Montagu), with which *Phascolion cæmentarium* (Quatrefages) is identical, and of which *Phascolosoma* (= *Phascolion*)

*tubicola* of Verrill is one of seven recognizable varieties, which are described in detail in this paper.

The genus *Aspidosiphon*, which hitherto has not been described as occurring off the Atlantic coast of North America, is found to be represented here by two new species. A new deep-sea species is added to the genus *Physcosoma* (= *Phymosoma*), remarkable for the continuity of its longitudinal musculature. The range of *Dendrostoma alutaceum*, which has been known as a West Indian form, proves to extend northward to Cape Hatteras. *Sipunculus* is found to be represented not only by the cosmopolitan *S. nudus*, well known to occur off the coasts of North Carolina and Florida, but also by *S. priapuloides* Koren and Danielssen, a deep-sea species, the range of which off the American coast extends from the latitude of Charleston, South Carolina, northward to that of New York City. *Siphonosoma cumanense* (Keferstein) (= *Phascolosoma cumanense* = *Sipunculus cumanensis*), an interesting example of Spengel's new genus *Siphonosoma*, hitherto recorded from the coast of Venezuela and the West Indies, is found to occur also in Florida.

It may be inferred from the large amount of sipunculid material in the National Museum from numerous northern stations that the collection is fairly representative of the fauna of this group within the area extending from Labrador to Cape Hatteras. The subtropical region southward from the latter point, however, has been less thoroughly explored, though southern Florida, at least, is known to be inhabited by many interesting forms.

It is the purpose of this paper to make this fauna available to biologists by presenting such descriptions of external features and internal structure as are necessary for the easy determination of species, by pointing out the variability of certain plastic forms that are suitable for experimental work, and by bringing together what is known about the geographical distribution of the group between Labrador and Key West. Since the material at hand will not permit of an account of the sipunculids of the West Indian and South American region that would be at all complete, I shall here describe such subtropical and tropical forms only as have been found along the coast of Florida.

It would be a profitable study, however, if sufficient material were available, to compare with one another the sipunculids of the two sides of the Isthmus of Panama. *Physcosoma agassizii* (Keferstein), *Aspidosiphon truncatus* Keferstein, and *Dendrostoma peruvianum* Colin, have been found, so far as I know, only in the Pacific, while *Physcosoma pectinatum* (Keferstein) and *Ph. antillarum* (Grube and Örsted), *Sipunculus nudus*, and *S. titubans* Selenka and Bülow occur on both sides of the Isthmus. The exclusively Atlantic subtropical species inhabiting the region southward from Cape Hatteras through

the West Indies are, according to Selenka (1883), the following: *Phascolosoma dissors* Selenka and De Man; *Phascolosoma coriaceum* Keferstein; *Phascolosoma pellucidum* Keferstein; *Phascolion strombi* (Montagu); *Physcosoma varians*<sup>1</sup> (Keferstein); *Dendrostoma alutaceum*<sup>1</sup> Grube; *Dendrostoma pinnifolium* Keferstein; *Sipunculus robustus* Keferstein; *Sipunculus phalloides* Pallas; *Sipunculus cumanensis vitrea*<sup>1</sup> Selenka and Bülow (now *Siphonosoma cumanense*, see p. 432).

To this list of subtropical forms should be added *Phascolosoma cylindratum* Keferstein; *Phascolosoma cinereum*, new species; *Phascolosoma verrillii* Gerould; *Aspidosiphon parvulus*, new species; *Aspidosiphon speciosus*, new species.

The sipunculid fauna of the latitude of the Middle States between Cape Hatteras and southern New England includes *Physcosoma capitatum*, new species (lat. 38° 41' N.); *Sipunculus priapuloides* Koren and Danielssen; *Phascolosoma cinctum*, new species; *Phascolosoma flagriferum* Selenka; *Phascolosoma margaritaceum* (Sars) var. *meridionalis*, new variety; *Phascolosoma procerum* Mœbius; *Phascolosoma verrillii* Gerould; *Phascolosoma sabellarix* Théel; *Phascolosoma improvisum* Théel.

The boreal fauna extending northward from Long Island, New York, includes *Phascolosoma gouldii* (Pourtalès); *Phascolosoma margaritaceum* (Sars); *Phascolosoma eremita* (Sars); *Phascolion alberti* Sluiter.

Ubiquitous along the American coast from the West Indies to Labrador is *Phascolion strombi* (Montagu). Its range includes the whole of the Arctic and North Atlantic Oceans and the Mediterranean Sea.

The most distinctively abyssal species of *Phascolosoma* that have been found off the eastern coast of America are *Phascolosoma flagriferum* Selenka, which occurs in 1,700–2,620 fathoms, and *Ph. cinctum*, new species, found in 368–1,290 fathoms. Associated with the latter at the depth of 1,290 fathoms was *Ph. sabellarix*. *Ph. eremita* (Sars), though commonly found in less than 100 fathoms, has been taken in 1,098; and *Ph. margaritaceum* (Sars), the typical form of which occurs off the Canadian and Newfoundland coasts in 30–75 fathoms, has a variety which I shall call *meridionalis* that has been taken off Marthas Vineyard in 705 fathoms. *Phascolosoma procerum* Mœbius has been found in 100–266 fathoms off our coast, its range apparently being somewhat restricted bathymetrically. It is found in the North Sea off Edinburgh, Scotland, as well as off the coast of the United States near the fortieth parallel. On the other hand, *Ph. sabellarix* and *improvisum* off this continent have a wide bathymetric range, the former occurring from 70 to 1,098 fathoms, the latter from 5 to 810.

<sup>1</sup> The species indicated have been found along the coast of Florida.

In shallow water are found *Ph. verrilli* (4-16 fathoms) and *Ph. cinereum* (45 fathoms). *Ph. gouldii* (Pourtalès) and *Ph. cylindratum* Keferstein are the littoral representatives of their genus upon this coast.

*Sipunculus nudus* Linnæus and *Siphonosoma cumanense* (Keferstein) var. *vitrea* are both littoral species, but *Sipunculus priapuloides* Koren and Danielssen is found in 478-1,069 fathoms.

*Phascolion strombi* (Montagu) occurs at all depths from 5 to 1,061 fathoms, and *Ph. alberti* Sluiter at depths of 1,267-1,674 meters.

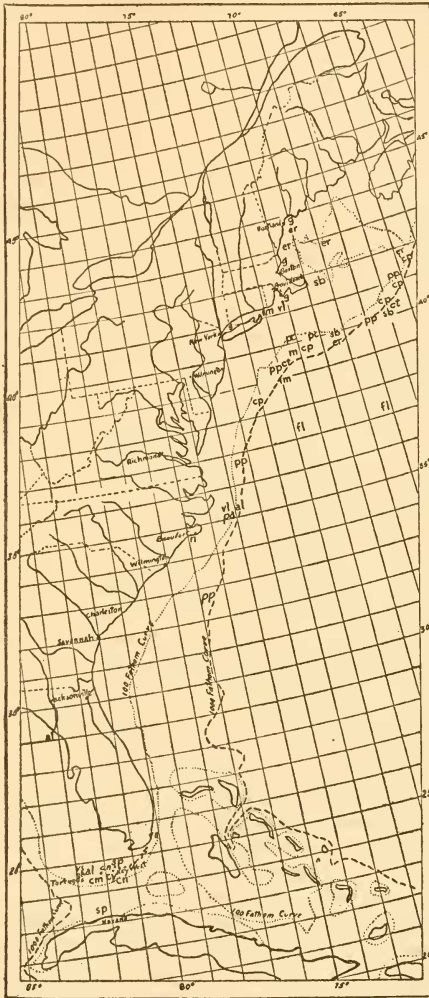
*Physcosoma varians* (Keferstein) and *Ph. antillarum* Grube and Örsted are littoral forms, but *Physcosoma capitatum*, new species, inhabits the sea bottom at 677-1,769 fathoms.

*Aspidosiphon parvulus*, new species, occurs in 16 fathoms; *A. speciosus*, new species, is found in the coral reefs near shore, and has been taken also at a depth of 157 fathoms.

*Dendrostoma alutaceum* Grube has a similar distribution among coral reefs near shore, and was taken off Cape Hatteras at a depth of 16 fathoms.

After plotting upon a map the principal localities at which sipunculids occur in the deeper waters off our coast (p. 377), I was interested to note how closely they follow the 1,000-fathom curve, the edge of the continental shelf. This is probably due in part to the fact that dredging operations have been carried on more extensively along this belt than elsewhere, but may it not possibly indicate that the conditions there, where the bottom rapidly descends from 100 to 1,000 fathoms, are exceptionally favorable for the life of sipunculids? *Sipunculus priapuloides*, *Physcosoma capitatum*, *Phascolosoma cinctum*, *Ph. procerum*, and *Ph. margaritaceum* var. *meridionalis* have been found only along this edge of the continental shelf; *Ph. eremita*, *Ph. sabellarix*, and *Ph. improvisum* occur not only there but in shallower waters nearer the coast. *Phascolosoma flagriferum* alone occurs beyond the 1,000-fathom line, isolated in the deep sea.

*Interrelationships of the genera.*—The recognized genera of sipunculids are so closely anastomosed that it is difficult to define them sharply from one another. For example, *Ph. gouldii*, which is clearly a species of *Phascolosoma*, as is shown by its tentacles, integument, arrangement of its nervous system, and its development, differs from all other species of *Phascolosoma* and resembles all known species of *Sipunculus* in the division of its longitudinal musculature into separate bands. On the other hand, *Physcosoma capitatum*, new species, differs from all other known species of that genus in having a continuous layer of longitudinal muscle fibers, and in this respect it resembles the *Phascolosomas*. Yet it has the peculiar form of head and crown of tentacles, as well as other features characteristic of the genus *Physcosoma*, in which I have accordingly, though it must be



Abbreviations: *at*, alutaceum, Dendrosotoma; *cm*, cumanense, Siphonotoma; *cn*, cinereum, Phascolosoma; *cp*, capitatum, Physcosoma; *ct*, cinctum, Phascolosoma; *cy*, cylindratum, Phascolosoma; *er*, eremita, Phascolosoma; *fl*, flagiferum, Phascolosoma; *g*, gouldii, Phascolosoma; *im*, improvisum, Phascolosoma; *m*, margaritaceum, Phascolosoma; *n*, nudus, Sipunculus; *pa*, parvulus, Aspidosiphon; *pc*, procerum, Phascolosoma; *pp*, prafapuloides, Sipunculus; *sb*, sabellaria, Phascolosoma; *sp*, speciosus, Aspidosiphon; *tl*, verrilli, Phascolosoma; *rs*, varians, Phascolosoma.

MAP SHOWING DISTRIBUTION OF ATLANTIC SIPUNCULIDS.

confessed, somewhat arbitrarily, placed it. The unity or division of the longitudinal musculature, therefore, though it is a convenient and useful recognition mark, is not, in my opinion, as perfect a criterion of genera as the peculiarities in the form of the crown of tentacles

*Phascolosoma* is the central genus with which *Sipunculus* and *Physcosoma* are each almost inextricably connected. The same can be said of the relation of *Phascolosoma* to *Dendrostoma*, *Petalostoma*, *Phascolion*, and *Aspidosiphon*. *Dendrostoma* and *Petalostoma*<sup>1</sup> differ from *Phascolosoma* only in their tentacles and the accompanying vascular system, both of which are hypertrophied in *Dendrostoma* and atrophied in *Petalostoma*. *Phascolion* is like *Phascolosoma* as regards its tentacular and circulatory apparatus, though it has become asymmetrical and otherwise modified in adaptation to life in mollusk shells. *Aspidosiphon*, while in its extreme forms widely divergent from *Phascolosoma*, is nevertheless closely connected with this genus by intermediate species, as it is with *Physcosoma*.

It is of course always difficult to form a definite opinion as to whether a simple organism is primitive or the product of degeneration, and in many, if not in most cases, no final conclusion can be reached in the absence of paleontological evidence. From my work on the embryology of *Phascolosoma* I was inclined to the conclusion that the sipunculids are extremely primitive, unsegmented, annelid-like forms, and am still of that opinion; but a fuller acquaintance with *Siphonosoma cumanense* might possibly give credence to the view expressed by Selenka that they are degenerate annelids. *Siphonosoma cumanense* (Keferstein) has *Phascolosoma*-like tentacles combined with certain of the characteristics of the genus *Sipunculus* and, in my opinion, is a form of considerable morphological interest, because its cœlom is crossed by regularly arranged transverse folds of peritoneum that suggest the dissepiments of annelids. The regularity of their arrangement and their independence of the intestinal coil suggest that possibly they may not be newly evolved peritoneal folds, as appears to be the case, but perhaps represent vestiges of the septa of annelid ancestors. A thorough study of the development of this species, in any event, is much to be desired.

The characters used in distinguishing species among the sipunculids are remarkably variable. Hooks, even though of some service in classifying these species, are unreliable, for in the same species they may be present or absent. In *Ph. gouldii*, for example, I found (1906) a zone of minute hooks encircling the introvert of young individuals 3-6 cm. long and probably 1 year old, while none were found on slightly larger individuals 6.7 to 8 cm. in length. *Ph. gouldii*, however, naturally would be included among hookless species, since the

<sup>1</sup> See pages 392, 395.

adult has no hooks. *Phascolion strombi*, on the other hand, is a species regularly provided with hooks, but occasionally lacking them.

The retractor muscles, which I regard as a feature of a good deal of morphological significance, vary in specimens of *Phascolion strombi* from off the coast of Nova Scotia in having two roots to the dorsal retractor instead of the usual single line of attachment, different individuals from the same region showing each condition. The divided retractor is often associated in these specimens with a short introvert, so that a more or less distinct variety may be recognized, which occurs with the normal form and probably interbreeds with it.

*Phascolion strombi*, in general, is an extraordinarily plastic form, its external features, like color, thickness of the integument, shape, and number of the cuticular holdfasts, apparently depending almost wholly upon the character of the shell which the individual inhabits. Experiments in raising this species in shells of different kinds would be most interesting and instructive, and, as the animals can readily be kept in aquaria, such experiments would be practicable at any permanent marine zoological station.

The order in which the genera are described in this paper is intended to bring out, in general, the fact that *Phascolosoma* is the central or primitive genus from which the others have probably originated, though the interrelationships of the various genera can be expressed, of course, only very inadequately by a linear series. *Siphonosoma* naturally would precede *Sipunculus*, since it is intermediate in structure between *Phascolosoma* and *Sipunculus*; but for convenience in description Professor Spengel's new genus is here placed last. The sequence adopted in this paper is as follows: *Phascolosoma*, *Phascolion*, *Dendrostoma*, *Physcosoma*, *Aspidosiphon*, *Sipunculus*, *Siphonosoma*.

#### Genus PHASCOLOSOMA F. S. Leuckart.

Longitudinal muscle layer continuous (except in *Ph. gouldii*). Distinct finger-shaped or leaf-shaped tentacles encircle the mouth in one or more rows or groups, interrupted in the median-dorsal line by the ciliated nuchal organ. Hooks may or may not be present on the introvert. The intestine forms a double spiral coil of several, or many, whorls not fastened at the posterior end of the trunk. The pair of nephridia hang free. Four retractor muscles of the introvert, or only two (ventral). The contractile Polian vessel in most cases is simple, seldom having cæca. An anterior columellar or spindle muscle usually occurs. A pair of photic tubes lead backward from the surface of a cerebral sense organ into the substance of the cerebral ganglion. The bottom (or posterior, blind end) of each of these tubes, when pigmented, forms an "eye spot."

The yolk-laden prototroch cells of the trochophore atrophy during metamorphosis, and their substance passes in granular form into the cœlom of the larva.

## SYNOPSIS OF SPECIES.

Four retractors....	{	Longitudinal muscles discontinuous.....	<i>gouldii</i> (Pourtalès).
		Longitudinal muscles continuous;	
		No hooks on introvert.....	<i>margaritaceum</i> (Sars).
		Hooks on introvert.....	<i>cylindratum</i> Kieferstein.
Two retractors....	{	Hooks absent.....	<i>procerum</i> Mœbius.
			<i>eremita</i> (Sars).
			<i>eremita</i> , new var. <i>scabra</i> .
		Hooks present.....	<i>verrillii</i> Gerould.
			<i>flagiferum</i> Selenka.
			<i>sabellarizæ</i> Théel.
		<i>improvisum</i> Théel.	
		<i>cinereum</i> , new species.	
		<i>cinctum</i> , new species.	

## PHASCOLOSOMA GOULDII (Pourtalès).

*Sipunculus gouldii* POURTALÈS, 1851.

*Phascolosoma gouldii* DIESING, 1859.

This common littoral species is found along the coast of New England from Casco Bay southward to the coast of Connecticut (New Haven), and on Long Island, New York (Cold Spring Harbor). It occurs somewhat locally in patches of muddy sand slightly above, or more commonly below, the low-water mark; and small individuals have been taken from Vineyard Sound with *Ph. verrillii* at a probable, though unrecorded, depth of several fathoms. The worms burrow vertically and obliquely in irregular fashion into the sand, to a depth of more than a half meter in summer.

This species, the structure of which has been fully described by Andrews (1890) and the development by Gerould (1896), requires no description here. I have elsewhere pointed out (1896, p. 147) that the division of the longitudinal musculature into distinct bands, which is a peculiarity that distinguishes this species from other *Phascolosoma*, is not an adequate reason for separating it from closely allied species of *Phascolosoma* and placing it in the genus *Sipunculus*, as Pourtalès, its earliest describer, Selenka, and others have done. In structure and development it much resembles *Phascolosoma vulgare* Blainville, the common littoral species of Europe. Its nearest ally in this country is *Ph. margaritaceum* (Sars), an inhabitant of deeper waters and extending northward, but also represented off our coast in the latitude of southern New Jersey by the variety *meridionalis*, the elongated form of which variety, as well as the integument and internal structure with the exception of the longitudinal muscles, resemble closely the corresponding features in *Ph. gouldii*.



## PHASCOLOSOMA MARGARITACEUM (Sars).

*Sipunculus margaritaceus* Sars, 1851.

*Phascolosoma oerstedii* KEFERSTEIN, 1865.—THÉEL, 1875.

*Phascolosoma fulgens* THÉEL, 1875 (young?).

*Phascolosoma albidum* THÉEL, 1875 (young).

*Phascolosoma margaritaceum* KOREN and DANIELSSEN, 1877.

Specimens were taken from the following localities off the coast of North America:

Station 2463, Green Bank, south of Newfoundland, lat. 45° 44' N.; long. 54° 27' W.; 45 fathoms, broken shells; temperature at bottom, 30° F.

Station 2466, Green Bank, south of Newfoundland, lat. 45° 29' N.; long. 55° 24' W.; 67 fathoms, coral; temperature at bottom, 30° F.

Gulf of St. Lawrence, J. T. Whiteaves, 1872; 30 fathoms. (Hitherto erroneously referred to by Verrill, 1874, and others as *Ph. boreale*.)

Station 2491, Misaine Bank, east of Cape Breton, lat. 45° 24' 30'' N.; long. 58° 35' 15'' W.; 59 fathoms, white sand.

Station 2492, Misaine Bank, east of Cape Breton, lat. 45° 22' N.; long. 58° 43' 45'' W.; 75 fathoms, white sand; temperature at bottom, 33.3° F.

Gloucester Donation 803, western edge of Grand Bank, schooner *Gatherer*, August 16, 1881.

*Characteristics*.—Smooth, firm skin of pearl gray color, lustrous in some specimens. Introvert brownish-gray in alcoholic specimens. Four retractors, no hooks on the introvert, no eye-spots. It can readily be distinguished from *Ph. gouldii* by the continuous layer of circular muscles of the body wall and by the shortness and greater thickness of the trunk.

In form and proportion (pl. 58, fig. 1) it resembles *Ph. eremita* (Sars), and especially smooth and lustrous specimens of the latter without internal examination might be mistaken for this species, but *Ph. eremita* has a rougher skin, marked with parallel ridges and furrows especially evident at the posterior extremity of the body, and the trunk is usually brownish, rather than pearl-gray. The two species can be readily distinguished otherwise by the fact that *Ph. margaritaceum* has four retractor muscles, *Ph. eremita* two.

*Distribution*.—Théel (1905) describes *Ph. margaritaceum* as a true Arctic form, possibly with a circumpolar distribution. A western variety occurs off Greenland, Spitzbergen, Norway (Finmarken), Russia (Kola Peninsula), and Nova Zembla; an eastern variety is found north of Siberia and in Bering Strait.

It is much less abundant off the coast of North America than *Ph. eremita* (Sars), but occurs at depths from 30 to 75 fathoms off Newfoundland and the Canadian coast.

## PHASCOLOSOMA MARGARITACEUM var. MERIDIONALIS, new variety.

Station 2749, lat.  $39^{\circ} 42'$  N.; long.  $71^{\circ} 17'$  W.; 705 fathoms, gray ooze; temperature at bottom,  $38.7^{\circ}$  F. One specimen, type.

Fayal Island, Azores, gravelly beach, lat.  $38^{\circ} 30'$  N.; long.  $28^{\circ} 40'$  W. Six specimens.

Type.—Cat. No. 4003, U.S.N.M.

This southern variety of *Ph. margaritaceum* occurs near the fortieth parallel on both sides of the North Atlantic, inhabiting the edge of the American continental shelf, 705 fathoms, in a region approximately south of Newport and east of Philadelphia; occurring also at Fayal Island, one of the Azores, where it burrows in a gravelly beach. The specimen from off the coast of the United States differs little except in size from those from the Azores.

The only marked difference between this variety and the typical form in northern waters is the extremely elongated shape, in which respect it resembles *Ph. gouldii*, or the two European species, *Ph. vulgare* and *Ph. elongatum*, more than the typical form. The introvert has the same pearly gray color as the trunk and not the brownish hue seen on the introvert of the typical form. The skin in a state of contraction shows distinct, though minute, papillæ. These are especially evident near the anterior end of the partially contracted introvert. The coils of the intestine are extraordinarily numerous in the large specimen from deep water (station 2749). The dimensions of this specimen are: Length of the trunk behind the anus, 85 mm.; introvert estimated at somewhat over 35 mm., probably half the length of the trunk; thickness of the trunk about 8 mm. The specimens from Fayal are about one-third as large as the specimen from station 2749.

One individual from Fayal lacks the left-dorsal retractor muscle.

*Ph. capsiforme* Baird is a small Antarctic species closely allied to *Ph. margaritaceum* (Sars). Geographically the variety just described occupies an intermediate region. Inhabiting waters of the Temperate Zone, its form resembles that of other Phascolosomas of this zone, rather than the oval form characteristic of the Arctic and northern type of this species and of *Ph. eremita* (Sars). It seems not impossible that the variety *meridionalis* may be a hybrid between the typical *Ph. margaritaceum* and *Ph. vulgare* or, possibly in the case of the Azores stock, *Ph. elongatum*.

## PHASCOLOSOMA CYLINDRATUM Keferstein.

Key West, Florida (Henry Hemphill, 1885). Three specimens.

Recorded previously only from the Bermudas, Keferstein (1865).

This small, littoral species (pl. 58, fig. 2) is easily distinguished by its smooth, light yellowish-brown surface, the rows of hooks behind its

finger-shaped tentacles, its cylindrical trunk and short introvert, and, internally, by the presence of four retractor muscles.

The length of one well-expanded specimen is: Trunk, 16 mm.; introvert, 5 mm.; another has a trunk 20 mm. long. The length of the introvert is therefore slightly less than one-third that of the trunk. The thin, smooth skin of the trunk is everywhere studded with minute epidermal organs, which are most clearly seen at the posterior end of the body, where the epidermis is marked off into small, squarish blocks, each containing a rounded epidermal organ. Slightly in front of this region the epidermal organs have an elliptical contour, as described by Keferstein. In most cases they do not rise above the general surface, though some of them near the posterior end of the trunk are capped with exceedingly minute papillæ. The larger part of the anterior half of the introvert is covered with about 20 distinct circlets of hooks. The anterior rows are more widely separated than the posterior, and consist of slender, curved, yellowish-brown hooks with dark-colored tips. The smaller, posterior hooks are less regularly arranged in circlets. Keferstein found 20 long thread-like tentacles. The one specimen which I examined had only 16, and they were short and finger-shaped, with a prominent longitudinal furrow along the oral surface of each, but they may have been somewhat contracted.

The dorsal retractors, which are more slender than the ventral, are attached to the body wall opposite the anus, and slightly behind the nephridial openings; the ventral retractors arise near the posterior end of the first third of the length of the trunk. There are numerous intestinal coils (25-30) which are free behind, though Keferstein notes that they are held behind and in front, respectively, by a pair of muscle strands. The rectum is very short. There is a short, simple contractile tube. The intestine is filled with calcareous particles—grains of coral sand.

#### PHASCOLOSOMA PROCERUM Mœbius.

Specimens were taken from the following localities off the American coast:

Station 871, lat. 40° 02' 54'' N.; long. 70° 23' 40'' W.; 115 fathoms, mud and fine sand; temperature at bottom, 49° F. One specimen.

Station 943, lat. 40° 00' 00'' N.; long. 71° 14' 30'' W.; 157 fathoms, mud, sand, shells; temperature at bottom, 49° F. Three young specimens.

Station 946, lat. 39° 55' 30'' N.; long. 71° 14' 00'' W.; 247 fathoms, green mud and sand; temperature at bottom, 47° F. One specimen.

Station 949, lat. 40° 03' 00'' N.; long. 70° 31' 00'' W.; 100 fathoms, yellow mud; temperature at bottom, 52° F. One specimen.

Station 999, lat. 39° 45' 13'' N.; long. 71° 30' W.; 266 fathoms, green mud. One specimen.

A specimen of this large gray *Phascolosoma* (pl. 58, fig. 3) was dredged at each of the above-mentioned localities off Marthas Vineyard at depths from 100 to 266 fathoms. In all respects except size they resemble those from Bass Rock near Edinburgh described by Mœbius, but the largest specimen from off Marthas Vineyard is five times the length of those from the North Sea. It has also been found at several places off the west coast of Sweden, according to Théel (1905), at depths of from 9 to 35 fathoms. In that region also its size is diminutive compared with that of the American specimens.

*Characteristics.*—The total length of the largest individual is 180 mm., of which the trunk behind the anus is 75 mm.; thickness of the trunk, 10 mm. The introvert is about  $2\frac{1}{2}$  times as long as the trunk, and one-third as thick. The posterior extremity of the body is prolonged into a slender, tail-like process, which in one specimen is about half as long as the thickness of the trunk, or about 5 mm. Color gray, the introvert of one specimen being slightly iridescent. The cuticula is thrown up into fine, wavy folds. Both trunk and introvert are covered sparsely with minute, dark-brown papillæ. The two (ventral) retractors have their origin at the extreme posterior end of the body (pl. 59, fig. 8). The pair of nephridia are attached slightly in front of the anus, and hang entirely free. Their surface is slightly rough. The esophagus is long; the rectum very short; the intestine has many coils closely held to the walls of the body. The Polian tube (contractile vessel) is covered with branching tufts that adhere to the dorsal wall of the body.

A notable feature of the nerve cord in two specimens that I have dissected is its submergence beneath the longitudinal muscle layer near the posterior end of the body, so that it is apparently interrupted. This disappearance begins slightly in front of the posterior end of the retractor muscles and extends forward nearly to the free ends of the nephridia. The retractors in this region are closely applied to the layer of longitudinal muscles, and united with them. Théel's (1905) beautiful figures of this species as it appears off the west coast of Sweden, however, show that the fusion of the retractor muscles to the body wall and the submergence of the nerve cord beneath the longitudinal muscles near the posterior end of the body, as described above, are not characteristic of the Swedish and North Sea representatives of this species, and it is perhaps not a constant characteristic in those of the western Atlantic.

According to Théel the tentacles are arranged in six groups, varying in number from 28 to 40. The skin immediately behind the tentacles is thin and smooth, not covered with the chitinous cuticula like the rest of the body, from which a collar or fold marks off this smooth zone.

## PHASCOLOSOMA EREMITA (Sars).

*Sipunculus eremita* Sars, 1851.

*Phascolosoma boreale* KEFERSTEIN, 1865.—VERRILL, 1874.

*Sipunculus (Phascolosomum) borealis* QUATREFAGES, 1865.

*Phascolosoma eremita* KOREN and DANIELSSEN, 1877.—SELENKA, 1883.—THÉEL, 1905.

Specimens were taken from the following localities off the American coast:

Station 2698, south of Newfoundland, lat.  $45^{\circ} 07' N.$ ; long.  $55^{\circ} 09' W.$ ; 90 fathoms, gray sand, pebbles.

Station 2486, east of Banquereau, Nova Scotia, lat.  $44^{\circ} 26' N.$ ; long.  $57^{\circ} 11' 15'' W.$ ; 190 fathoms, coarse sand and gravel; temperature at bottom,  $39.7^{\circ} F.$

Station 2507, off Halifax, Nova Scotia, lat.  $44^{\circ} 27' 30'' N.$ ; long.  $62^{\circ} 33' 30'' W.$ ; 80 fathoms, hard bottom; temperature at bottom,  $41.6^{\circ} F.$

Station 2497, off Cape Canso, south of Cape Breton, lat.  $45^{\circ} 04' N.$ ; long.  $59^{\circ} 46' 45'' W.$ ; 57 fathoms, yellow sand, broken shells, hard; temperature at bottom,  $33^{\circ} F.$

Casco Bay, 1873; 48-64 fathoms.

Station 21B, Cashes Ledge, lat.  $42^{\circ} 49' N.$ ; long.  $68^{\circ} 50' W.$ ; 52-90 fathoms, rocky bottom; temperature,  $43^{\circ} F.$

Station 78B, east of Isles of Shoals near Jeffreys Ledge, lat.  $43^{\circ} 04' N.$ ; long.  $70^{\circ} 30' W.$ ; 35 fathoms, blue clay, mud, sand; temperature at bottom,  $43^{\circ} F.$

Station 161, off Cape Ann, a little south by west of lat.  $42^{\circ} 36' N.$ ; long.  $70^{\circ} 27' W.$ ; 54 fathoms; temperature at bottom, about  $39\frac{1}{2}^{\circ} F.$

Station 216, off Cape Ann; 35 fathoms, sandy.

Station 184, off Cape Ann, a little northeast of lat.  $42^{\circ} 30\frac{1}{4}' N.$ ; long.  $70^{\circ} 38' W.$ ; 45 fathoms, mud; temperature at bottom,  $42\frac{1}{2}^{\circ} F.$

Station 2523, east of Georges Bank, lat.  $41^{\circ} 48' 30'' N.$ ; long.  $65^{\circ} 44' 30'' W.$ ; 111 fathoms, sand, gravel, stones; temperature at bottom,  $41.6^{\circ} F.$

Station 2524, east of Georges Bank, lat.  $41^{\circ} 48' 45'' N.$ ; long.  $65^{\circ} 47' W.$ ; 85 fathoms, sand, gravel, stones; temperature at bottom,  $42.6^{\circ} F.$

Station 891, south of Marthas Vineyard, lat.  $39^{\circ} 46' N.$ ; long.  $71^{\circ} 10' W.$ ; 480 (?) fathoms, soft brown mud.

Station 2052, south of Georges Bank, lat.  $39^{\circ} 40' 05'' N.$ ; long.  $69^{\circ} 21' 25'' W.$ ; 1,098 fathoms, Globigerina ooze; temperature at bottom,  $45^{\circ} F.$

This species is found from Spitzbergen and Greenland eastward to Nova Zembla and the Kara Sea (Théel, 1905). The southernmost point off the Scandinavian coast at which it has been taken is Bodö, north of the Arctic Circle (Koren and DanielsSEN, 1875, 1877, cited

by Théel, 1905). It is remarkable that this characteristically Arctic form extends southward along the American coast in shallow water as far as Massachusetts Bay, and in deeper waters as far south as about 40° north latitude.

Specimens that I have examined from the extreme north (South Gatt, northwestern Spitzbergen, latitude 79° 40' N., 7 fathoms, and others from Spitzbergen Sea dredged by the U. S. S. *Alliance* in 1881) do not differ materially from those found in Massachusetts Bay.

It occurs usually at depths of less than 100 fathoms, though Théel records a specimen from Umanak, Greenland, from 200 fathoms, and it has been found south of Cape Cod in 480 and 1,098 fathoms.

The specimens in the United States National Museum differ only in minor details (size, color) from Keferstein's (1865) description of *Ph. boreale*, which has been identified by Danielssen and Koren as *Ph. eremita* (Sars). These differences are (1) the slightly smaller size of the specimens in the National Museum, none of which is more than 25 or 30 mm. in total length, including a slight allowance for contraction, although it is quite possible that the living animal may measure 20 to 50 mm., which Selenka (1883) gives as the length of *Ph. eremita*. (2) The introvert in the specimens from off the New England coast is shorter than the trunk (pl. 58, fig. 4), whereas in *Ph. eremita* (= *boreale*) it is said to be as long as or longer than the trunk. The dimensions given by Keferstein, however (trunk 18 mm., introvert 15 mm.), agree as to proportions with the specimens which I have examined. (3) I find no gray, yellow, or yellowish-brown pigment spots on the specimens (preserved in alcohol) that I have examined, such as have been found in this species.

The skin is usually dark grayish- or yellowish-brown and, in some specimens, has a slight iridescence. The most constant and striking characteristic of the skin is the occurrence of parallel transverse ridges and furrows (pl. 58, fig. 4) which everywhere encircle the body, but are especially constant at the posterior extremity, which in some cases is raised into a knob-shaped elevation surrounded by concentric ridges. In many individuals the transverse ridges are broken, particularly at the posterior extremity of the body and at the base of the introvert, by less prominent longitudinal ridges.

Very minute, finger-shaped papillæ (in many specimens darker than the rest of the skin, and hence easily visible with a lens) are scattered somewhat sparsely, but rather evenly, over the surface. The papillæ are somewhat more abundant, however, at the base of the introvert and near the posterior extremity of the trunk than elsewhere. They are found upon the ridges and, at the posterior end of the body, upon the squarish blocks of skin into which the ridges are broken. The skin and body wall are thick and tough in most individuals.

There are 22-24 simple tentacles in the specimens which I have examined, produced by the slight modification of a tentacular fold. Théel (1905) finds, among the many specimens from the northern and Arctic regions that he has examined, from 16 to 40 tentacles. Each has the usual longitudinal furrow on the oral surface. A simple nuchal organ consisting of a pair of elevations lies in the mid-dorsal interruption of the tentacles.

The longitudinal muscles form a continuous layer. The two retractors (fig. 1) have their origin in the middle third of the body. A pair of prominent gonads were found attached to their bases. The nephridia are small and hang free. The brain is not distinctly bilobed, and is without visible eye-spots. There is a well-marked cerebral organ. The alimentary tube has numerous coils. The esophagus is attached to each of the retractor muscles by a peritoneal membrane containing muscle fibers. The intestinal coil hangs free behind, but is held at the anterior end by two muscle strands, one attached to the junction between the esophagus and descending spire, united to the body wall on the left; and one attached to the third coil and to the right side of the body wall. There is no spindle muscle, but a transverse sheet of muscle holds the short rectum to the wall of the body. There is a simple Polian tube.

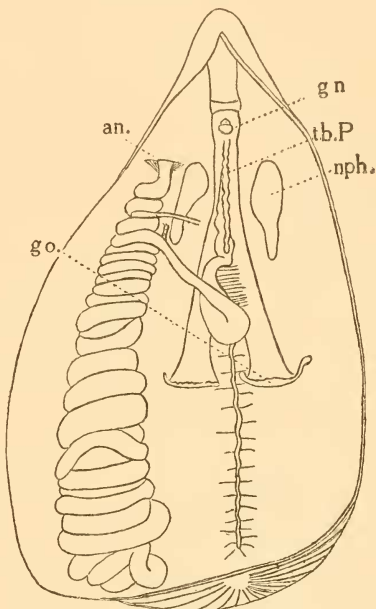


FIG. 1.—DISSECTION SHOWING INTERNAL STRUCTURE OF PHASCOLOSOMA EREMITA. X 4, an, ANUS; gn, CEREBRAL GANGLION; go, REPRODUCTIVE ORGANS; nph, NEPHRIDIUM; tb. P, POLIAN TUBULE.

PHASCOLOSOMA EREMITA (Sars) var. SCABRA, new variety.

Specimens, which may be designated as representatives of a new variety, *scabra*, were dredged with *Phascolion strombi* and a species of *Dentalium* probably off Cashes Ledge in the Gulf of Maine in 1873. The shape of the contracted specimens indicates that they may have been taken, like the Phascolions, from cast mollusk shells.

Type.—Cat. No. 8396, U.S.N.M.

They differ from the typical form in that the circular ridges and furrows of the external surface are nearly concealed by the loose, thick, coffee-colored cuticula, which gives the surface the appearance of a rough woolen fabric. In one of these specimens the brain is distinctly bilobed, and the nephridia are long, but there are no constant internal peculiarities that I can discover.

Specimens from Casco Bay have a similar, though less marked, scabrous appearance, and certain individuals from off Cape Ann show the same tendency.

#### VARIATIONS FROM GREAT DEPTHS.

The single specimen taken at station 2052, south of Georges Bank, 1,095 fathoms, differs markedly in external appearance from the typical form. It has a thick, rough, grayish integument thickly covered at the posterior extremity of the trunk with bluntly rounded papillæ.

The imperfect specimen from station 891, south of Marthas Vineyard, 480 fathoms, on the other hand, has a smooth, thin skin suggesting that of *Ph. margaritaceum*.

#### PHASCOLOSOMA VERRILLII Gerould.<sup>1</sup>

Station 15, south of Naushon Island, Massachusetts,  $7\frac{1}{2}$  fathoms, rocks and sand. One specimen.

Station 79, north of Nashawena Island,  $5\frac{1}{2}$  fathoms, mud. One specimen.

Station 93, off north shore of Naushon, 7-8 fathoms, sandy mud. One specimen.

Station 135, mouth of West Falmouth Harbor,  $3\frac{3}{4}$ -5 fathoms, sand and pebbles. Two specimens.

Station 7811, off West Falmouth, Massachusetts,  $6\frac{3}{4}$  fathoms. Three specimens.

Station 1188 (year 1884), off Nobska Point,  $4\frac{1}{2}$ -5 fathoms, hard sand.

Off Tarpaulin Cove (south of Naushon).

Station 2280 (1884), off Cape Hatteras, lat.  $35^{\circ} 21' N.$ ; long.  $75^{\circ} 21' 30'' W.$ , 16 fathoms, gray sand and broken shells. Six specimens.

This species occurs in the shallow waters of Vineyard Sound and Buzzards Bay, Massachusetts, and extends southward as far at least as Cape Hatteras, and probably farther. The biological survey of the Woods Hole region carried on by Dr. F. B. Sumner in 1905 and 1906 brought to light eight specimens, and four others from Vineyard Sound and six from off Cape Hatteras had already been preserved in the U. S. National Museum. I secured one specimen off West Falmouth in August, 1907, by dredging with the *Phalarope*,

<sup>1</sup> Science, vol. 27, No. 691, March 27, 1908.



but several hauls made for this purpose in the same locality with the larger apparatus of the *Fish Hawk* were unsuccessful.

The depth at which it has been taken varied from  $3\frac{3}{4}$  to 8 fathoms about Woods Hole, and was 16 fathoms off Cape Hatteras. It occurs either in sand or mud, or a combination of the two.

The largest specimens that I have examined have a total length of 25 mm., of which the trunk is 15 mm., the introvert about 10 mm. (pl. 58, fig. 5). The somewhat thick, cylindrical trunk (thickness one-tenth to one-fifth of the length) tapers rapidly to a blunt end behind. The slender cylindrical introvert has a uniform diameter except at the base, where it expands slightly as it joins the trunk. Its diameter is less than half that of the trunk (as, for instance, 1 mm. to 2.5 mm. in a specimen with a total length of 25 mm.).

There is a single row of 34 tentacles, or less. A young individual, 7 or 8 mm. in length, has 12. There are no hooks on the introvert.

This species has the peculiar possibility, under adverse conditions, of withdrawing the introvert from the thick cuticula which covers it. The cuticula is first loosened, and then sloughed off, but retained as a tubular, or trumpet-shaped, protuberance from the anterior end of the body, like the proboscis of an echiurid (pl. 59, fig. 7). This malformation does not prevent the alternate introversion and extension of the anterior end of the animal, though the anterior extremity of the introvert with the tentacles can not be completely expanded. This peculiar result of unfavorable circumstances appeared in both of the living specimens that I examined, the first being in that condition when taken from the dredge, the second assuming it after an attempt had been made to stupefy the animal with weak alcohol.

The color varies from dark-seal brown, or dark-steel gray with iridescent tints and dark-brown papillæ, to light brown, or more exactly café-au-lait. The color probably depends upon the nature of the bottom. The seal-brown specimens were taken from a sandy or pebbly bottom; the iridescent steel-gray specimen from sandy mud, and the light-brown specimen from mud. Ripe males, if not too deeply pigmented, are easily distinguished from the females by the white color of the sperm shining through the translucent walls of the body.

Both trunk and introvert are covered with prominent papillæ of a darker hue than the rest of the skin (pl. 58, fig. 5). They are largest and most crowded at the posterior end of the trunk and at the base of the introvert, smallest and least abundant in a broad zone in the middle of the trunk, and gradually increase in size and abundance from this zone backward to the posterior extremity. Likewise on the introvert the papillæ decrease gradually in size and abundance from the base to the region immediately behind the tentacles, which are nearly devoid of papillæ. The large papillæ on the base of the intro-

vert and at the posterior end of the trunk are finger-shaped, or bluntly conical, and attached to the body by a small neck. On the introvert of a large individual they measure 0.08 mm. or 0.09 mm. in length and 0.033 mm. to 0.038 mm. in breadth, but on another specimen they are from 0.04 mm. to 0.05 mm. long and about 0.03 mm. in thickness. In the middle of the trunk the larger papillæ are ovate and fungiform, about 0.04 mm. in diameter. Smaller, undeveloped papillæ are interspersed among the others.

The two (ventral) retractor muscles (fig. 2) arise from the body wall in the adult slightly in front of the middle of the trunk. In a

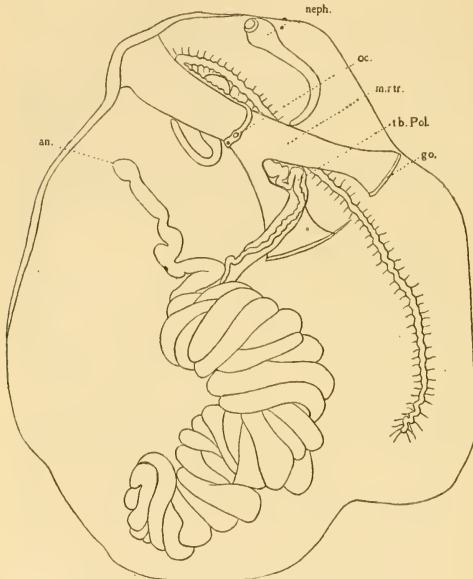


FIG. 2.—DISSECTION OF PHASCOLOSOMA VERILLI.  $\times 9$ . *an.*, ANUS; *go.*, REPRODUCTIVE ORGANS; *m. r. tr.*, RETRACTOR MUSCLE; *neph.*, NEPHRIDIUM; *oc.*, PIGMENTED EYE; *tb. Pol.*, POLIAN TUBULE.

very young individual (7 mm.—8 mm. in length) they were found to arise at the posterior end of the second third. The relative position of the attachments of these muscles evidently shifts forward in this form, as in other sipunculids, during the post-larval life, owing to excessive growth of the body wall at the posterior pole. (See Gerould, 1906, p. 119.)

The pair of large nephridia are situated nearly opposite the anus,

but slightly in front of it. A prominent ciliated nephrostome opens into the ventral side of the base of the nephridium. Its circular orifice communicates with a narrower passage which runs backward close to the ventral wall of the nephridium and parallel to the latter into the cavity of the nephridium, from which a septum partially separates it. The length of the passage is three or four times the width of the orifice.

The supraesophageal ganglion of the adult is oval, or spindle-shaped, with its chief axis transverse to the length of the body. A

pair of prominent pigmented eyes lie within the brain near its anterior, dorsal, and lateral surfaces. They consist of the pigmented posterior extremities of a pair of slender, cylindrical ocular tubes, which run forward to the lateral surfaces of an oval epidermal protuberance in front of the brain, the cerebral organ. This organ lies dorsal to the buccal region and anterior to the ciliated nuchal organ. The ocular tubes are filled with a transparent, homogeneous material (fluid or semifluid) which does not readily stain, in the midst of which lies a long, spindle-shaped, refractive cone, which stains readily with fuchsin. Its chief axis coincides with that of the tube.

The intestine consists of about 26 whorls. It is of wide caliber, and terminates in a long, straight rectum. A large simple Polian vessel runs the length of the esophagus upon its dorsal side.

*Phascolosoma verrillii*, which has a southern range, resembles *Ph. pellucidum* Keferstein (= *Ph. riiseii* Keferstein) in its proportions, in internal structure, including the presence of pigmented eye-spots, but the skin is not so thin as in the latter, and the papillæ are perhaps not so slender and spine-like. *Ph. pellucidum* from St. Thomas (Antilles) measures, according to Keferstein, trunk 45 mm., introvert 23 mm.; the hookless individuals which Keferstein calls *Ph. riiseii* measure, trunk 40 mm. and introvert 20 mm., so that this species is more than twice as long as *Ph. verrillii*.

Professor Verrill (1873) mentions this form in his Report on the Invertebrate Animals of Vineyard Sound, page 333 [627] as "A species similar to the last [*Ph. cæmentarium*] in size and form, with a thick integument, thickly covered throughout with small rounded papillæ or granules, but without the dark chitinous hooks seen on the posterior part of the latter." He possibly refers to it again on page 59 [353] under the "Fauna of the sandy shores of the bays and sounds." It appears to have been found with *Ph. gouldii* in the sand at low water, evidently by digging. Again on page 122 [416] it is mentioned as occurring with *Ph. cæmentarium* on gravelly and shelly bottoms.

Since Professor Verrill thus briefly described this species it is appropriately known as *Ph. verrillii*, in recognition of the large contributions to science of this veteran naturalist and distinguished pioneer of American zoology.

#### PHASCOLOSOMA FLAGRIFERUM Selenka.

Station 2566, latitude of Cape Charles, Virginia, 37° 23' N.; long. 68° 08' W.; 2,620 fathoms; bottom temperature, 36.4°; gray ooze. Two specimens.

Previous records:

Selenka (1885), *Challenger*, station 44, lat. 37° 25' N.; long. 71° 40' W.; 1,700 fathoms; bottom temperature, 36.2°; blue mud; also from the Pacific Ocean, *Challenger* station 241, lat. 35° 41' N.; long. 157° 42' E.; 2,300 fathoms; bottom temperature, 35.1°; red clay.

Sluiter (1900), station 757, off Cape Finisterre, Spain, lat.  $44^{\circ} 06'$  N.; long.  $12^{\circ} 41'$  W.; 4,900 meters; clay mud.

Two specimens were taken by the Fisheries steamer *Albatross* in 1885 with a trawl in the same region at which the *Challenger* took a specimen in 1873—that is, east of Cape Charles, Virginia, and southward from Cape Cod. Another specimen was dredged by the Prince of Monaco off Cape Finisterre, Spain, and two specimens by the *Challenger* from the Pacific Ocean, east of Japan. It is found in the deep sea at a depth of 1,700 to 2,678 fathoms.

The posterior end of the elongated trunk is prolonged into a slender flagellum.<sup>1</sup> Flat, oval papillæ projecting forward, a half millimeter long, are found near the posterior extremity of the trunk, which elsewhere appears smooth. Slender, finger-shaped papillæ are found upon the introvert. There are no hooks.

The trunk of the specimen that is intact measures about 60 mm., the introvert about 40 mm. Selenka's largest specimen was 130 mm. in total length; Sluiter's, with largely retracted introvert, 120 mm. The color of the trunk is yellowish-brown, with pigment at the anterior extremity, which probably gives the bluish color in that region noted by Sluiter. The slender, thin-walled introvert is of a lighter color. The anus is prominent, and the openings of the nephridia are situated slightly in front of it, opposite each other. Selenka describes a circlet of finger-shaped tentacles, which are heart-shaped in cross section.

The coils of the intestine are numerous. It is free behind, but a spindle muscle holds it in front (Selenka). The nephridia are free. There is a simple contractile tube.

PHASCOLOSOMA SABELLARÆ Théel.

[=PHASCOLOSOMA (PETALOSTOMA) MINUTUM Keferstein?].

A large number of these minute, transparent sipunculids were taken by the Fisheries steamer *Albatross* in 1883 from station 2084, south of Georges Bank, lat.  $40^{\circ} 16' 50''$  N.; long.  $67^{\circ} 05' 15''$  W., in 1,290 fathoms, where the bottom is of gray mud and sand and the temperature  $40^{\circ}$  F. One specimen was also taken from each of the following stations in the same general locality: Station 1095, lat.  $39^{\circ} 55' 28''$  N.; long.  $69^{\circ} 47'$  W.; 321 fathoms soft green mud; temperature at bottom,  $40^{\circ}$  F.; station 2571, lat  $40^{\circ} 09' 30''$  N.; long.  $67^{\circ} 09'$  W.; 1,356 fathoms, gray Globigerina ooze; temperature at bottom,  $37.8^{\circ}$  F; and two from off Chatham, Massachusetts, station 372, lat.  $41^{\circ} 40'$  N.; long.  $69^{\circ} 28\frac{1}{2}'$  W., in 70 fathoms and from a sandy bottom.

The largest specimens measure in contracted conditions about 8 mm. in total length, that of the trunk being 5-6 mm., and the introvert may be estimated as being nearly as long as the trunk. In

<sup>1</sup> For figures see Selenka (1885), pl. 3, fig. 17, and Sluiter (1900), pl. 1, fig. 3.

Théel's description the total length of the largest specimen (expanded) is 15 mm., proboscis more than one-third of the total length. The introvert is slender and cylindrical, and is marked off from the trunk in certain of the American specimens by a slight dorsal hump on which the anus is situated, or by an annular elevation about that region, though some specimens do not show these features. The skin is smooth, except that a few minute epidermal organs are found at the base of the introvert and at the posterior extremity of the trunk (fig. 3). The epidermal organs consist of a crater-like ring of four or five cells rising slightly above the surface, surrounding a minute,

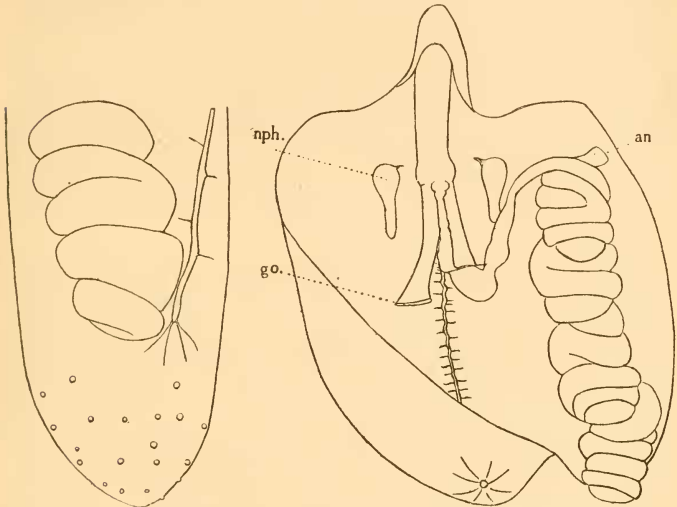


FIG. 3.—POSTERIOR EXTREMITY OF PHASCOLOSOMA SABELLARIE SHOWING PAPILLÆ.

FIG. 4.—DISSECTION OF PHASCOLOSOMA SABELLARIE.  $\times 13\frac{1}{2}$ . an, ANUS; go, REPRODUCTIVE ORGAN; nph, NEPHRIDIUM.

slender, transparent cuticular elevation. The body wall is thin and transparent.

Théel states that the tentacles are represented by irregular, rounded prominences of the oral disk, and that hooks are absent, though he found in rare cases (1 per cent) a few small ones.

The two ventral retractor muscles (fig. 4) are attached slightly behind the middle of the trunk, the pair of nephridia suspended nearly opposite the anus. They hang free, and are easily broken off in dissection. There are no eye spots. The nerve cord terminates slightly in front of the posterior end of the body, and a pair of nerves runs backward between the circular and longitudinal muscles.

The esophagus is long, the rectum rather short; the intestinal coil, which is free behind, consists of about 13 double turns (Théel, 1905), and extends backward to the posterior end of the cœlom. The esophagus is held to the retractors by a few muscle strands, but no supporting fibers were elsewhere observed. (Théel's fig. 175 shows the supporting fiber of the esophagus attached to the body wall rather than to the retractor.) Théel states that the parts of the retractors that have united anteriorly are always longer than their remaining separate portions, and the same is apparently true of the American specimens, though Paul (1909) shows that in a specimen from the coast of Sweden, which he sectioned transversely, the fusion occurs through about the middle fifth only, the muscles of the anterior two-fifths being separate.

The sexes in the specimens that I have examined from off the American coast appear to be separate, the males when full of sperm being whitish, and easily distinguished from the females. Some males contain immature sperm in oval or pear-shaped masses, which viewed with a hand lens might be mistaken for eggs. The body cavity of the female contains relatively few large, opaque eggs. In no case do I find any evidence of hermaphroditism.

Théel found no males of this species, though he considered it possible that the papillate *Ph. improvisum* Théel which was taken at the same locality might be the male. Paul (1909), comparing *Ph. sabellarix* with *Phascolosoma (Petalostoma) minutum* Keferstein from the coast of France, arrives at the conclusion that both are of the same species and both hermaphrodites. The evidence which he presents on both of these points, however, is not entirely satisfactory, and especially is this true of the supposed hermaphroditism of *Ph. sabellarix*. His figures of the reproductive organ of *Ph. minutum* in section (figs. 5 and 21) have the appearance of a typical ovary, though containing groups of cells supposed from their size and the density of their chromatic contents to be spermatocytes. In sections of the ovary of *Ph. gouldii*, I find clusters of small cells of a similar appearance beneath the peripheral oocytes, but, though I have examined the cœlomic fluid of hundreds of individuals of both sexes in this species, in no case have I ever found both ova and sperm in the same individual. Paul, in referring to the ovaries of *Ph. sabellarix*, makes this statement bearing on the question of sex (p. 30): "Doch finden sich auch die Zellgruppen wieder, die Ich bei *Petalostoma minutum* als vermuthlich männliche bezeichnet habe. Die verschiedenen Entwicklungsstadien von beiderlei Geschlechtszellen treiben genau so in der Leibeshöhle umher, wie bei *Petalostoma minutum* beschrieben wurde." Professor Spengel, likewise, in whose Institut Paul's work was done, writes me that *Ph. sabellarix* and *Ph. improvisum* are at least extraordinarily like *Ph. minutum*, and that he is quite certain of

the hermaphroditism of *minutum*, in reference to which he says: "Paul hat sicher neben den Eiern immer Spermien und ihre Bildungsstadien angetroffen, wie er es beschrieben hat, und das auch bei ein und demselben Individuum von *Ph. sabellarix* Théel."

In view of such trustworthy testimony I have made a renewed search for evidences of hermaphroditism in the specimens from station 2084, but the examination of three males full of sperm and of several females containing oocytes gives only negative results, though it does not of course exclude the possibility of hermaphroditism if we assume, as Paul does, that an individual may successively produce ova and thereafter sperm.

If further investigation should show that these forms from European waters are identical and hermaphroditic, and that the one just described from the American coast is dioecious, it may be necessary to give the latter a new name; in which case I would suggest *Phascolosoma diaphanes*, new species. In other respects the American form closely resembles the form described as *Ph. sabellarix* Théel, and varies only slightly (in the thinness of the body wall) from the earlier described *Phascolosoma (Petalostoma) minutum* Keferstein.

PHASCOLOSOMA IMPROVISUM Théel.

[=PHASCOLOSOMA (PETALOSTOMA) MINUTUM Keferstein?].

Under this name Théel (1905) described a form with distinct papillæ on the posterior end of the trunk and on the introvert, and a girdle of hooks behind the short, rounded tentacles. Otherwise this type appears to be identical with *Ph. sabellarix* Théel, and Paul (1909) regards both forms as identical with *Petalostoma minutum* Keferstein. However this may be, I shall tentatively apply the name to certain small sipunculids in the United States National Museum from the following localities:

Station 2234, lat. 39° 09' N.; long. 72° 03' 15'' W. (east of New Jersey) in green mud, from 810 fathoms; temperature at bottom, 38.6° F. One specimen.

Station 549, off Niantic Bay, Connecticut, from a sandy bottom, 5 fathoms. Twelve specimens.

Thus it appears that this form lives in shallow water near the shore, as is the case in Sweden, but it also is found at a long distance from shore and at a depth of 810 fathoms. In these respects it resembles the closely allied or identical form *Ph. sabellarix* Théel in this country, which in Sweden has been found only near the shore with *Ph. improvisum*.

The largest specimen was the one taken from the off-shore station, the trunk of which measures 10 mm. The largest specimen from Niantic Bay has a total length of 13 mm. (introvert 5 mm., trunk 8 mm.). Another has an introvert of 3 mm., a trunk of 4.5 mm.

The surface of the skin is smooth, with prominent papillæ at the posterior end of the trunk. Those elsewhere are exceedingly small, and on the anterior part of the trunk they are reduced in number and size almost to the vanishing point, though minute papillæ similar in size to those on the middle zone of the trunk are uniformly distributed over the introvert.

In certain preserved specimens, like the one taken at station 2234, local contraction of the integument at the posterior and anterior ends of the trunk produces the erroneous impression of permanent shields, as in *Aspidosiphon*.

The two retractor muscles (fig. 5) are attached to the body wall not far from the middle of the length of the trunk, but there appears to be a good deal of variation in this respect, as Théel has also found. They are joined together near their posterior attachments to form one. In one of the two specimens dissected, the posterior extremities of the two retractors were bound together by a transverse muscular cord.

The long esophagus lies dorsal to the united retractor muscle, and passes into a many-coiled intestine which joins a short rectum.

The short, cylindrical nephridia taper slightly, and are attached to the body immediately behind the zone in which the anus lies.

So far as I have examined these few specimens I have found none with eggs, which was also the condition which Théel found in the Swedish specimens,

and which led him to suppose that this might be the male of *Ph. sabellarix*. The American specimens of the male of the latter species, however, as I have already stated, are smooth, whitish individuals easily distinguishable from this papillate, slightly more opaque form.

PHASCOLOSOMA CINEREUM, new species.

A specimen was taken from south of Key West (station 2317), lat.  $24^{\circ} 25' 45''$  N.; long.  $81^{\circ} 46' 45''$  W., at a depth of 45 fathoms and from a bottom of coral sand and temperature of  $75^{\circ}$  F. The contracted trunk is 14 mm. long, 7 mm. thick. Introvert very short, 4 or 5 mm. in length.

*Type*.—Cat. No. 4087, U.S.N.M.

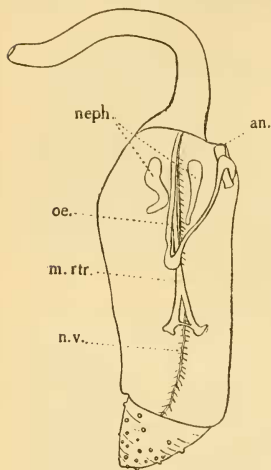


FIG. 5.—DISSECTION OF PHASCOLOSOMA IMPROVISUM FROM OFF NIAN TIC BAY, CONNECTICUT, IN FIVE FATHOMS, STATION 549. INTESTINAL COIL NOT SHOWN.  $\times 13\frac{1}{2}$ . an, ANUS; m. rtr, RETRACTOR MUSCLE; neph, NEPHRIDIUM; n. v, VENTRAL NERVE CORD; oe, ESOPHAGUS.



Color ashen gray; introvert of a lighter shade; trunk covered with minute brown papillæ, which at the posterior end of the body are long and finger-shaped, ovate with a slender stalk (fungiform) in the middle of the trunk, and bluntly conical at the anterior extremity. Those of the introvert are much finer and cylindrical. A narrow zone of minute, dark-colored, irregularly placed hooks (fig. 6) lies immediately behind the tentacles. Body wall tough and opaque. The cuticula, which resembles that of *Ph. procerum*, is thrown up into sinuous longitudinal folds near the posterior end of the trunk.

The inner surface of the body wall is smooth and lustrous, of a violet-brown color. A single pair of strong, completely separate ventral retractor muscles (fig. 7) are attached to about the middle of the trunk. The pair of nephridia hang free from the body wall opposite the anus. The contractile tube is without cæca. The esophagus is held by fine muscle strands to the retractors. There are about 15 whorls in the intestinal coil, which is held by a muscle



FIG. 6.—HOOKS FROM INTROVERT OF PHASCOLOSOMA CINEREUM. X 290.

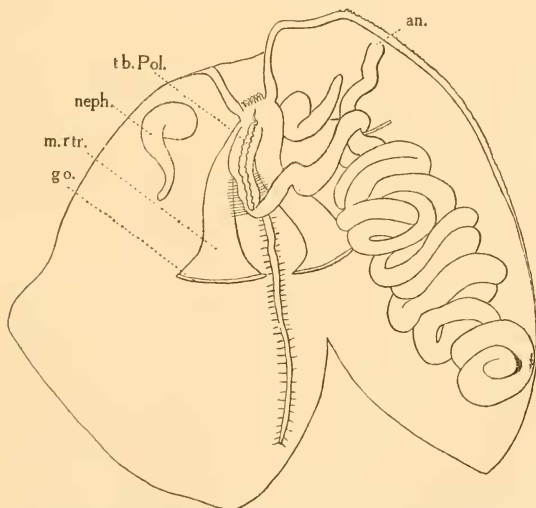


FIG. 7.—DISSECTION OF PHASCOLOSOMA CINEREUM. X 5½. an, ANUS; go, REPRODUCTIVE ORGANS; m. rtr, RETRACTOR; neph, NEPHRIDIUM; tb. Pol, POLIAN TUBULE.

strand on each side of the first turn, but free behind. The rectum is short. There are no eye-spots.

This species most nearly resembles *Ph. coriaceum* described by Keferstein (1865) as occurring also among the West Indies, at St. Thomas. *Ph. cinereum* is similar to *Ph. coriaceum* in the size and proportions of the trunk and introvert, in the retractor muscles, and in the general appearance of the papillæ, but it differs from this species in several respects: The hooks of *Ph. cinereum* are slenderer, and are restricted to a narrow zone immediately behind the tentacles, not widely scattered over the anterior half of the introvert; the tentacles are probably less numerous and larger, though the single contracted specimen at hand does not permit an accurate comparison; the papillæ at the posterior extremity of the body are not fungiform, as represented in *Ph. coriaceum* by Selenka (1883, pl. 5, fig. 53), but long and finger-shaped; the color is gray, not yellowish-brown (Selenka, pl. 1, fig. 15); the contractile tube is simple, without cæca which give it a tufted appearance in *Ph. coriaceum*; the rectum of *Ph. cinereum* is short, not longer than the intestinal coil as in *Ph. coriaceum*.

PHASCOLOSOMA CINCTUM, new species.

Station 994, lat. 39° 40' N.; long. 71° 30' W.; 368 fathoms, mud; temperature at bottom, 40.5° F. Type.

Station 2084, lat. 40° 16' 50'' N.; long. 67° 05' 15'' W.; 1,290 fathoms, blue mud and sand; temperature at bottom, 40° F.

Type.—Cat. No. 8328, U.S.N.M.

*Chief characteristics*.—Two weak retractor muscles. Introvert about one-half the length of the trunk, when both are expanded. Coarse, isolated, circular muscle fibers are prominent, especially in the introvert, which is marked off obliquely and sharply from the trunk. A zone of fine recurved hooks around the introvert, immediately behind the head. Prominent papillæ near the posterior end of the trunk. Inhabits empty tubes of *Hyalinæcia*.

The two specimens of this remarkable sipunculid (pl. 59, fig. 6) were taken off Marthas Vineyard at the above-mentioned stations. At the former *Ph. procerum* also occurs; at the latter a large number of specimens of *Ph. sabellarix* Théel were found. The larger of the two specimens is partially inclosed in a fragment of a *Hyalinæcia* tube, which fits closely about the body.

The total length of the specimen from station 994, which was evidently stretched out in its tube when it died, is 30.5 mm., of which the introvert is 6 mm. or about one-fifth the length of the trunk. The other specimen, the introvert of which is perhaps fully expanded, measures about 13 mm., of which the introvert is 6 mm., the trunk 7 mm. It is probable that the trunk of the latter specimen is much contracted, as is the introvert of the former.

The slender, cylindrical introvert is united to the thicker trunk by an oblique line of junction extending from the region of the anus

ventrad and cephalad (pl. 59, fig. 6). About three rows of delicate, recurved hooks lie in the zone immediately behind the tentacles. The wall of the introvert is thinner and more translucent than that of the trunk. The circular muscle fibers in this region are coarse and so prominent as to cause in certain places slight circular elevations of the epidermis. They are separated from one another by rather wide intervals, whereas the underlying longitudinal muscle fibers, which are much finer than the circular fibers, form a continuous layer. The action of the strong, isolated circular muscle fibers is evident in the trunk by numerous constrictions that occur in the extended specimen and by the tendency of the body wall to become torn transversely. Parallel longitudinal ridges appear prominently in the epidermis of the contracted trunk.

Conspicuous oval papillæ occur near the posterior extremity. At the extreme tip of the body, however, the papillæ are exceedingly small, gradually but rapidly increasing to the maximum size from behind forward. Inconspicuous papillæ are scattered over the entire trunk and introvert. They are largest and most numerous immediately behind the base of the introvert, and exceedingly small in the middle of the trunk and upon the introvert.

The two specimens differ in color. That which occurs with *Ph. procerum* is, like that species, gray; the other is grayish-brown, but

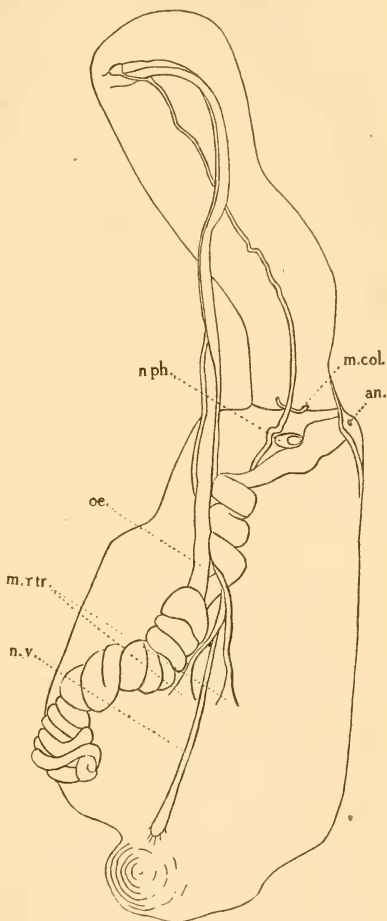


FIG. 8.—DISSECTION OF PHASCOLOSOMA CINCTUM, STATION 2084.  $\times 13\frac{1}{2}$ . an, ANUS; m. col, COLLAR MUSCLE; m. rtr, RETRACTOR MUSCLE; nph, NEPHRIDIUM; n. v, VENTRAL NERVE CORD; oe, ESOPHAGUS.

the posterior extremity and papillæ of that region are yellowish brown.

The longitudinal muscles of the body wall consist in the trunk, as in the introvert, of exceedingly fine fibers that form a continuous layer. The single pair of somewhat slender, dark brown retractors (fig. 8) are attached in the posterior half of the body, slightly behind the middle of the trunk and, in the specimen examined, approximately three-fourths of the distance from the head to the posterior end of the body. In the trunk they are cylindrical and extremely slender, but are expanded into a flat fan shape at their posterior attachment. In the introvert they closely ensheathe the narrow esophagus. In the specimen dissected one was twisted sharply about the other in the region where the rectum joins the esophagus. At the base of the introvert a narrow slip of circular muscle fibers extends into the body cavity from the body wall ventral to the nerve cord, and encircles not only the nerve cord but also the esophagus and the retractor muscles. It serves as a muscular collar, holding in position the long retractor muscles, which are everywhere else free except at their terminal points of attachment.

The nephridia (fig. 8) are short and slipper-shaped with a wide nephrostome, and are situated nearly opposite, but slightly behind, the anus. Only the right one was seen. The nerve cord is a flat band. The long esophagus joins an intestine of about 16 coils.

#### Genus PHASCOLION Théel.

This genus is composed of small sipunculids showing a marked asymmetry in the development of the nephridia and reproductive organs and often a spirally twisted body, adaptations to life in empty shells of gasteropods and scaphopods. They also live in the tubes of annelids or in those of their own construction. There is a single row of tentacles around the mouth, and numerous recurved hooks often occur in a zone behind the tentacles. In most species numerous attaching papillæ or holdfasts, each capped with a chitinous denticle projecting forward, occur in a broad band encircling the body near its posterior end. Only one nephridium is developed, and it lies posterior to the anus. The intestine is not thrown into spirals, but into loops extending forward and backward and held to the body wall by several strands of muscle fiber. One or two retractor muscles are found; in the latter case the dorsal in most species is larger than the ventral.

The Phascolions of our coast have the characteristic holdfasts upon the posterior half of the trunk, each capped with a sharp arrow-head-shaped or crescentic chitinous denticle. Only the right nephridium is developed, and the gonad is unsymmetrically situated, curving around the right side of the origin of the ventral retractor muscle, near the posterior end of the body. The ventral retractor

being attached to the body wall by two roots, the gonad crosses the right root.

The intestine has six characteristic loops, the first, third, and fifth extending forward, the second, fourth, and sixth backward; the fifth hangs free, but the others are bound to the body wall by muscle strands.

The opinion advanced by Selenka (1883) that the various species of *Phascolion* have arisen from *Phascolosoma* appears to be well founded. Such a change would have involved the almost complete fusion of the two dorsal and likewise of the two ventral retractor muscles to form in each case one. Selenka also expressed the belief that *Phascolion* has arisen by several distinct stems. However that may be, the individuals of the North American coast form a fairly homogeneous, though variable, group.

With the possible exception of *Phascolion alberti* Sluiter, all of these eastern forms will be most satisfactorily considered as forming a single species, formerly known as *Ph. cæmentarium* (Quatrefages), but which is identical with the widespread *Ph. strombi* of Europe, as I have determined by comparing specimens from the west coast of Sweden with those from the eastern coast of North America.

*Ph. strombi* in America, as elsewhere, shows a remarkable variability in size, color, thickness of the body wall, size of the papillæ and holdfasts, and hence in the smoothness or roughness of the skin. The internal organization is more stable, though the eggs vary in shape, in the thickness of the yolk membrane and in the amount of yolk. In certain localities off Halifax the dorsal retractor shows a tendency to a division at the base into two roots, but this in no region is a constant character.

The extraordinary plasticity of the external characteristics of *Ph. strombi* make it a favorable animal upon which to study experimentally the effect of the environment upon form. According to Théel (1875), moreover, it is remarkably tenacious of life, and is readily kept alive for more than a month in ordinary aquaria, so that it would no doubt live well under such modification of external conditions as such experiments would demand.

A study of the very large number of specimens of this species in the U. S. National Museum has convinced me that the most striking variations in the external features are due in large measure to the environment. Thus the introvert is relatively short in individuals that have adapted themselves to the narrow tubes of *Protula*, *Hyalinæcia*, or *Pectinaria*, in comparison with the trunk which is greatly elongated by compression within the slender tube. Such individuals also have a smooth and often lustrous skin, especially in the region of the holdfast near the posterior end of the body. Furthermore, they show no external signs of a spiral twist, whereas those which

inhabit the cast shells of gasteropods are twisted. The latter have the posterior extremity of the body made smooth by the compression within the apical whorl of the shell, the holdfasts are small, the skin is thin and white. On the other hand, those which live in cement tubes constructed by chætopods or by themselves have prominent papillæ at the posterior end, strong, sharp holdfasts, and a thick, colored skin. Many such comparisons readily occur to one who has examined a large number of specimens of the varieties presently to be described.

Little is known of the development of *Phascolion*. It would be of much interest to learn whether the asymmetry of the adult is manifest in the youngest larvæ by the appearance of a single nephridium, viz, the right, or whether the pri nordium of the left nephridium appears and subsequently becomes atrophied.<sup>1</sup> Are the retractor muscles of the larva paired or single? The answer to this question might perhaps furnish evidence in favor of the supposed origin of *Phascolion* from an ancestral *Phascolosoma* with paired retractors. In the larva of *Phascolosoma* these muscles are distinctly paired.

<sup>1</sup> This question has been partially answered by L. A. Moltchanoff, 1909, in Bull. Acad. Sci., St. Petersburg, ser. 6, vol. 3, pp. 69-74, 5 figs., who shows that in *Ph. spitzbergense* Théel, which Théel later identified as a form of *Phascolion strombi* (Montagu), the left nephridium is represented in the adult by a vestigial canal passing through the wall of the body.

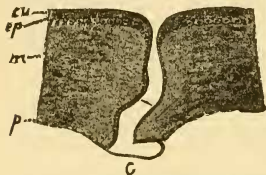


FIG. 1.—AFTER MOLTCHANOFF. TRANSVERSE SECTION OF THE ATROPHIED LEFT NEPHRIDIUM OF PHASCOLION. c, BODY CAVITY; cu, CUTICULA; ep, EPIDERMIS; m, MUSCULAR LAYER; p, PERITONEUM. (Oc. 1, Syst. 6, Leitz.)

Moltchanoff adds that "Neither Brumpt nor Théel mentions atrophied nephridia in *Phascolion strombi* (Montagu). It would be very interesting to study sections of the corresponding region in *Phascolion strombi* to ascertain whether the canal of the atrophied nephridium shows the peculiarity of the eastern *Phascolion*, from Mourman, or, which is most probable, whether it does not exist in *Phascolion* from the west, though undescribed because it has never been seen."

I regret that this matter came to my attention too late for further investigation. It is indeed probable that this vestige of the left nephridium occurs in *Phascolion strombi* of the American coast, though I have never observed it in dissections nor examined sections through that part of the body wall where it is likely to be found.

is as follows: "The left nephridium is not completely absent. Sections show clearly that there exists on the left, symmetrically with the well-developed nephridium, a small canal, which connects the cœlom with the surrounding medium. (Fig. 1.) The structure of its walls resembles that of the corresponding portion of the well-developed right nephridium. Its internal orifice is situated upon a small elevation; it is clearly visible in examining with a hand lens the corresponding part of the dermo-muscular sac. As far as I have been able to see, it is almost completely closed by the peritoneum, but nevertheless the passage seems to exist. The function of the nephridium in question is entirely obscure, because it appears that the expulsion of the genital products takes place exclusively through the right nephridium; as for the excretory function of this canal, its rôle can not be considered as of much importance."

SYNOPSIS OF SPECIES AND VARIETIES OF PHASCOLION.

Posterior attachment of dorsal retractor usually undivided, that of ventral with two roots.	{  <i>Phascolion strombi</i> (Montagu), 16-26 tentacles.	{  Introvert longer than the trunk.	{  (a) Common form, orange- brown or yellowish- brown. Range from Labrador southward to 40° N. lat. . . . var. <i>fusca</i> . (b) Dark-colored, with thick skin, sharp hold- fasts. . . . . var. <i>tubicola</i> . (c) Small, white form in gasteropod shells, com- mon in region of Woods Hole, Mass. . . . var. <i>alba</i> . (d) Deep-sea form with short, thin-walled trunk, large opaque, ovoid eggs . . . . . var. <i>hyalina</i> .
	{  <i>Phascolion alberti</i> Sluiter.	{  Introvert of about the same length as trunk, in shells of <i>Protula</i> and <i>Dentalium</i> . Off Cape Cod, and near the 40th parallel. Elongated, smooth; 16 tentacles. Eggs ovoid. . . . . (e) var. <i>gracilis</i> . Introvert shorter than the trunk; dorsal retractor in some individuals is divided at the base. Blends, and probably freely interbreeds with var. <i>fusca</i> . . . . . (f) var. <i>canadensis</i> .	{  Introvert two-thirds the length of the trunk; papillæ of anterior and middle part of the trunk provided with chitinous denticles, pointing forward. Chitinous cap of papillæ at posterior end of trunk oval. Off Newfoundland (Prince of Monaco, 1887), 1,267 meters. Off Cape Finisterre, 1,674 meters.
Dorsal retractors, as well as ventral, probably with two roots, introvert longer than the trunk and, like the posterior end of the trunk, smooth. Constructs a tube with an additional slender sheath for the introvert.			

PHASCOLION STROMBI (Montagu).

*Sipunculus strombus* G. MONTAGU, Trans. Linnean Soc. London, vol. 7, 1804, pp. 74-76.  
*Siphunculus dentalii* GRAY, Spicilegia Zoologica, London, 1828, p. 8.  
*Sipunculus bernhardus* FORBES, A History of British Starfishes, London, 1841, pp. 251-253.  
*Sipunculus (Phascolosoma) concharum* ØRSTED, De regionibus marinis, Diss. phil. Haun., Hauniæ, 1844, p. 80, and Krøyer's naturh. Tidskrift, p. 419.  
*Phascolosoma strombi* DIESING, Systema Helminthum. Vindob., vol. 2, 1851, p. 65.  
*Phascolosomum dentalii* DIESING, Systema Helminthum. Vindob., vol. 2, 1851, pp. 64-65.

- Phascolosoma bernhardus* POURTALES, Proc. Amer. Ass. Adv. Sci., Meeting of 1851, p. 41, Washington, 1851.
- Sipunculus (Cryptosomum) cæmentarium* QUATREFAGES, Histoire Nat. des Annélés marins et de l'eau douce, vol. 2, Paris, 1865, p. 628.
- Phascolosoma hamulatum* PACKARD, Mem. Boston Soc. Nat. Hist., vol. 2, 1867, p. 290.
- Phascolosoma cæmentarium* VERRILL, Report Invert. Animals Vineyard Sound, in First Report of the U. S. Comm. of Fish and Fisheries, Washington, 1873, p. 627, pl. 18, fig. 92; also same in separate reprint, Washington, 1874.
- Phascolosoma tubicola* VERRILL, Amer. Journ. Sci. and Arts, ser. 3, vol. 5, 1873, p. 99; also Proc. Amer. Ass. Adv. Sci., Meeting of 1873, pp. 388, 389, 1874.
- Phascolion strombi* THÉEL, Bihang till k. Svenska Vet. Akad. Handl., vol. 3, No. 3; also No. 6, pp. 13, 14, Stockholm, 1875.
- Phascolion spitzbergense* THÉEL, Bihang till k. Svenska Vet. Akad. Handl., vol. 3, 1875, p. 16, pl. 1, figs. 2, 3.
- Sipunculus capitatus* H. RATHKE, Nova Acta Acad. Leop. Car., vol. 20, 1843, pp. 143-147, pl. 6, figs. 20-23.

This abundant and widespread species is found in America from Labrador southward to the West Indies. It occurs in shallow waters of about 5 fathoms off the Elizabeth Islands, is abundant everywhere along the coast at depths varying from 20 to 150 fathoms, which naturally have been more thoroughly explored than the deeper waters, and appears to be by no means uncommon along the edge of the continental shelf in from 150 to 1,000 fathoms. The greatest depth of which I have a record is 1,061 fathoms at station 2207, just south of the fortieth parallel.

I have seen no specimens from farther south than station 2728, in 859 fathoms, north of Cape Hatteras but slightly south of the latitude of Norfolk, Virginia. Selenka (1883), however, mentions the occurrence in the West Indies of *Ph. tubicola* (Verrill), which I have ascertained to be a local variety of this species. The specimens which Selenka examined differ from the typical form in that the ventral retractor has only a single root. I have observed this same characteristic in some of the specimens from off the southern coast of the United States, though it is not by any means a constant characteristic of specimens from that region. (See "Modifications in the South," p. 415.) The ventral retractor in *Ph. strombi* in general, however, with a uniformity that is remarkable for this variable species, has two distinct roots, and the same is true of the local variety from off the New England coast which Verrill originally described as *Phascolosoma tubicola*. But the subtropical form is evidently so nearly like its more northern relatives that to exclude it from the same widespread and variable species on this ground alone would be to lay undue stress on a single characteristic of minor importance.

*Phascolion strombi* is common in the Arctic Ocean, occurring in abundance off the northern coast of Asia, the northern coast of Europe, Spitzbergen, Iceland, and both the eastern and western coasts of Greenland (Théel). It extends southward in Europe along



the coasts of the British Isles, France, and in the Mediterranean. It is probably the most common sipunculid throughout at least the northern part of its range, which comprises the whole of the Arctic and North Atlantic Oceans and the Mediterranean Sea.

The size of *Ph. strombi* varies greatly in different localities. The largest specimens that I have examined are from off Portsmouth, New Hampshire (station 76B, 51 fathoms), the contracted trunk of which measures 20 mm. long, 7 mm. thick, but the largest specimens from most localities have a trunk of about 15 mm.—17 mm. in length and 4 mm.—5 mm. in thickness. The slender, cylindrical introvert is longer than the trunk (fig. 9). It is impossible to determine the exact dimensions of either introvert or trunk from preserved specimens that have died in various states of contraction, and I have not had the opportunity to examine the live animals, but, judging from the numerous preserved specimens, it appears that the length of the introvert varies from a dimension only slightly greater than that of the trunk to about twice the length of the latter.

The white variety from the shallow waters about Woods Hole and off Block Island is much smaller.

The shape of the body depends upon that of the tubes or shells which the animals inhabit. Those which live in gasteropod shells acquire a spiral twist. On the other hand, in most localities they live in tubes of their own construction (pl. 60, fig. 10) or in deserted tubes of *Pectinaria*, *Protula*, *Hyalinæcia*, or *Dentalium*, and accordingly show only a slight tendency toward a spiral twist, visible merely in the retracted introvert.

The mouth of the cast shell or the tube inhabited by individuals of this species from off the American coast is partially closed with a hollow cone composed of a cement made of mud or fine sand, often inclosing minute pebbles, and held together by a secretion. These cones sometimes rise as much as 5 mm. above the mouth of the shell in the form of a funnel. I have found a small amount of cemented muddy sand in shells of *Dentalium* occupied by *Ph. strombi* from the west coast of Sweden, sent me through the kindness of Prof. H. J. Théel, though I judge from the fact that no mention has been made by European observers of cement formation in this species that it never is a conspicuous phenomenon in shells occupied by *Ph. strombi* in Europe, these shells being lined with loose mud or sand. It was

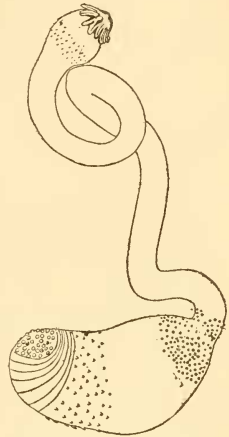


FIG. 9.—PHASCOLION STROMBI.  
× 4.

chiefly on the basis of this habit of cementing together the muddy sand that Quatrefages (1865) observed in specimens from North America that he gave the name *Sipunculus cæmentarius* to these specimens. The tubes of cement are usually slightly curved, and are marked on the exterior at regular intervals by annular furrows. (Pl. 60, fig. 10.)

The color of the animal varies from a very dark brown or a grayish-brown (variety *tubicola*), orange-brown or yellowish-brown (variety *fusca*) to white (variety *alba*). The dark brown specimens from certain regions have a decidedly purple hue, which is especially common in the grayish-brown individuals that live in *Pectinaria* tubes.

Light yellowish-brown or orange-brown is the color of the widely distributed typical form, as seen in specimens from Labrador, the coast of Nova Scotia, from off Eastport, off Point Judith, and farther south. The color of the local varieties will be mentioned in the descriptions that are to follow.

There are 16 tentacles (pl. 60, fig. 12) in the specimens from comparatively shallow waters off the coast of Maine and Massachusetts, but the number in other localities is 20, 24, or 26; 20 occur in specimens from off Nova Scotia (stations 44-46); 24 in individuals from 300 fathoms off Norfolk, Virginia (station 898); 26 in specimens from south of the Grand Banks of Newfoundland (station 2437). The number in two specimens figured by Théel (1904) is respectively 16 and 26, and I find 26 in a specimen from the east coast of Sweden sent to me by Professor Théel.

A zone of recurved hooks, disposed irregularly, occurs a short distance behind the tentacles (fig. 9).

Prominent papillæ cover the anterior part of the trunk and the proximal part of the introvert (pl. 60, fig. 11); elsewhere the body is provided with minute papillæ which are variable in size, abundance, and distribution in the different varieties.

The characteristic holdfasts (Haftpapillen), or papillæ crowned with triangular, arrow-shaped, chitinous hooks pointing forward, occur in a wide band (fig. 9) which extends from a little behind the middle of the trunk backward nearly to the posterior end, which in individuals that live in shells or tubes with smooth walls is smooth, or covered with minute papillæ, although specimens from tubes of cement usually have rather prominent papillæ upon the posterior extremity of the body. The holdfasts are variable in size, shape, and color; especially is this true of the varieties *gracilis* and *canadensis*. The shape of the chitinous cap is typically like an inverted U or V. The variety *alba*, which is found in gasteropod shells has U-shaped holdfasts; those of the thick-skinned variety *tubicola*, inhabitants of tubes of cement, are in general more pointed.

*Internal structure.*—The longitudinal muscles of the body wall form a continuous layer with a smooth, shining cœlomic surface.

The dorsal retractor (fig. 10) is large, and has its origin immediately behind that of the two roots of the ventral retractor at the posterior extremity of the body, in a single wide, flat sheet which is unsymmetrically attached to the left and dorsal sides of the body. The attachment of the left border of the muscle is close behind that of the ventral retractor, in the median plane of the body, whence the line of attachment runs dorsad across the left and dorsal sides of the body wall for a distance of slightly more than 180° of arc. The ventral retractor is attached to the body wall typically by two short roots between the posterior end of the nerve cord and the origin of the dorsal retractor. The ventral retractor is very slender, as compared with the large, thick, dorsal retractor.

The alimentary tube (fig. 10) consists of (1) a slender anterior division held to the ventral side of the body by several muscle fibers and terminating in a loop attached by a strong strand of muscle fiber to the left of the nerve cord a short distance in front of its posterior end, and (2) a second division, made of one chief loop attached on the right side of the posterior end of the body immediately behind the right edge of the dorsal retractor. This second loop consists of a

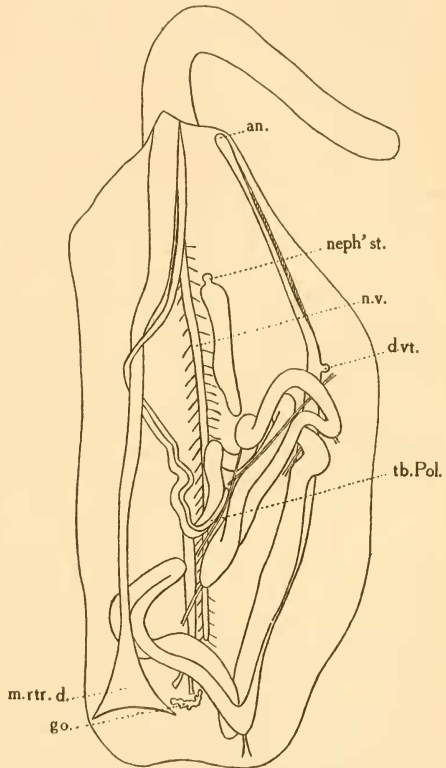


FIG. 10.—DISSECTION OF PHASCOLION STROMBELI.  $\times 6\frac{1}{2}$ . *an.*, ANUS; *divt.*, DIVERTICULUM; *go.*, REPRODUCTIVE ORGAN; *m. rtr. d.*, DORSAL RETRACTOR MUSCLE; *neph'st.*, NEPHROSTOME; *n. v.*, VENTRAL NERVE CORD; *tb. Pol.*, POLIAN TUBULE.

wide, thin-walled portion, a twisted part showing a tendency to form a coil, and a straight rectum, on which a small diverticulum is found. The anus lies at a considerable distance (2 or 3 mm.) in front of the nephrostome. A simple Polian tube of wide caliber extends along the dorsal side of the esophagus to a point considerably beyond that at which the alimentary tube leaves the ventral retractor.

The single (right) nephridium is large, and extends in specimens of the common variety about half the distance between the nephrostome and the posterior extremity of the body. It is closely attached along its ventral line to the wall of the body by several strands.

The reproductive organ is situated on the right side of the posterior end of the body cavity, a convoluted ridge, beginning close to the posterior end of the ventral nerve cord and extending obliquely over the base of the right root of the ventral retractor, on a line continuous with that of the attachment of the dorsal retractor.

#### VARIETIES.

The most interesting fact in regard to this species is its extraordinary plasticity, its tendency to form modifications and probably germinal variations. How far this diversity in external features is due to the direct action of the environment, as, for instance, the kinds of empty shells or tubes which the worms inhabit, their food supply, temperature of the water, etc., and how far it may be determined by heredity are questions which can be answered fully, of course, only by breeding and rearing the animals.

#### PHASCOLION STROMBI var. TUBICOLA (Verrill).

This variety is identical with *Phascolosoma tubicola* described by Verrill (1873) as a new species based on certain superficial features which were believed to distinguish it from the earlier described *Ph. cæmentarium* (Quatrefages). I have dissected a sufficient number of specimens in the National Museum named by Verrill "*tubicola*" to determine from a study of their internal as well as external structure that this form is identical with *Ph. strombi*, of which it is a local variety extending from Casco Bay to the waters about Cape Ann. I have retained Verrill's term *tubicola* as a varietal name out of respect for the rule of priority in nomenclature, though it is not a distinctive descriptive expression. The variety that I have called "*fusca*," for example, is a tubicolous form the range of which overlaps that of *tubicola*. A better descriptive term for this variety would be *pullacea*.

Verrill describes it as having the posterior end of the body "transversely wrinkled and rough, and covered with small round, somewhat raised verrucæ or suckers." The holdfasts, or triangular chitinous hooks, are said to be more numerous, sharper, and darker-colored

than in the typical *Ph. cæmentarium* (= *strombi*). The papillæ of the anterior part of the body are more prominent, the skin is darker, thicker, and more opaque, and Verrill found no hooks upon the introvert. The habitat of the form is "Off Casco Bay, 60 to 94 fathoms; near St. George's Bank, 85 to 150 fathoms."

A part of the specimens that I have examined from Casco Bay and the most of those from around Cape Ann correspond to Verrill's description, except that, like other varieties of *Ph. strombi*, they have a zone of hooks upon the introvert. The well-known fact that the hooks of the introvert are deciduous in some sipunculids makes the presence or absence of hooks, however, of little moment.

PHASCOLION STROMBI var. FUSCA, new variety.

The dark-colored, markedly papillate variety just described is by no means sharply differentiated from the common widely spread form with smoother skin (particularly at the posterior end of the body) and usually of a light yellowish-brown or orange color. This common form is found from Labrador southward at least as far as Point Judith and the deeper water along the edge of the continental shelf near the fortieth parallel (stations 793, 871, 895, 1093). It is found at intervals between these extreme localities and even in the same general region where the swarthy variety, *tubicola*, occurs. Thus specimens from near the Isles of Shoals (stations 44B and 76B) and off Nahant (station 30) have the color and other features of the typical form, except that the papillæ at the posterior end of the trunk and elsewhere are prominent, just as in individuals of the variety *tubicola* from the neighboring Cape Ann region.

*Type*.—Cat. No. 8373, U.S.N.M. From Gulf of Maine, str. *Bache*, 1873.

PHASCOLION STROMBI var. ALBA, new variety.

It is obvious that the kind of shell or tube in which individuals of this species live has much to do in determining their extraordinarily variable appearance. Thus a well-marked form which may be described as variety *alba* is found in small gasteropod shells in the shallow waters about Woods Hole, the Elizabeth Islands, Point Judith (station 799, 13 fathoms), and off Block Island (station 815, 15 fathoms).

Specimens of this variety are about two-thirds the size of the typical form, with a trunk 10 mm. in length and introvert 15–20 mm., for example. The color is white or gray. The surface of the body is remarkably smooth, especially at the posterior end, where the minute, slender, conical papillæ are hardly visible with a hand lens magnifying 10 diameters. The nipple-shaped papillæ upon the base of the introvert and the adjacent part of the trunk are visible with a lens, but the conical papillæ upon the introvert are exceedingly minute. A broad zone immediately behind the tentacles is studded

irregularly with numerous slender, sharp, recurved hooks, dark brown at the tip. The chitinous holdfasts near the posterior end of the trunk are blunt, U-shaped, and of a light yellowish-brown color.

*Type*.—Cat. No. 16323, U.S.N.M. From Station No. 79, north of Nashawena.

PHASCOLION STROMBI var. HYALINA, new variety.

Two specimens of this remarkable form, which should possibly rank as a distinct species, were dredged from 238 fathoms at station 895, near the fortieth parallel, south of Marthas Vineyard (type locality). Another small female came from 365 fathoms in the same region (station 894). All were inhabitants of the tubes of the annelid, *Hyalinæcia*.

The body of a contracted specimen is nearly cylindrical, with somewhat truncated extremities. The larger specimens, with the introvert completely retracted, are 22–25 mm. in length and 4–5 mm. in diameter; the smallest, a sexually mature female, is 10 mm. long, 2 mm. in diameter. The introvert in the contracted specimens is about two-thirds the length of the trunk, and the conclusion may be safely drawn that its length in the living animal does not exceed that of the trunk.

The body wall is thin, translucent, of brownish-gray color with a pearly luster. The skin is smooth, the papillæ at the posterior extremity of the trunk being minute and those at the anterior extremity not conspicuous. No papillæ are found in the region of the holdfasts or in the adjacent middle third of the trunk. The holdfasts are light brown, capped with a sharp point extending forward.

The retractor muscles resemble those of other varieties in that the attachment of the dorsal muscle is single, whereas that of the ventral has two roots, but the attachment of the latter is at the extreme posterior end of the body opposite that of the former, and not slightly in front of it as in other varieties. The single (right) nephridium is remarkably short. The eggs are large, oval, and opaque,  $150\mu$  by  $170\mu$ , or  $150\mu$  by  $160\mu$  in diameter (in alcohol). The above measurements were taken from eggs from the cœlom of the small female, the trunk of which was only 10 mm. long, and hence it is evident they are large as compared with the size of the body. Eggs of the common variety, *fusca*, from Boon Island, for example, are only  $106\mu$  in diameter, though eggs throughout the species vary much in size and in translucency.

*Type*.—Cat. No. 15119, U.S.N.M.

PHASCOLION STROMBI var. GRACILIS, new variety.

Station 921, lat.  $40^{\circ} 07' 48''$  N.; long.  $70^{\circ} 43' 54''$  W.; 67 fathoms, green mud.

Station 922, lat.  $40^{\circ} 03' 48''$  N.; long.  $70^{\circ} 45' 54''$  W.; 71 fathoms, green mud and sand.

Station 949, lat.  $40^{\circ} 03'$  N.; long.  $70^{\circ} 31'$  W.; 100 fathoms, yellow mud.

Station 998, lat.  $39^{\circ} 43' N.$ ; long.  $71^{\circ} 32' W.$ ; 302 fathoms, green mud.

Station 1025, lat.  $39^{\circ} 49' N.$ ; long.  $71^{\circ} 25' W.$ ; 216 fathoms, green mud.

Station 1038, lat.  $39^{\circ} 58' N.$ ; long.  $70^{\circ} 06' W.$ ; 146 fathoms, sand and shells.

Station 2177, lat.  $39^{\circ} 33' 40'' N.$ ; long.  $72^{\circ} 08' 45'' W.$ ; 87 fathoms, green mud and sand.

Stations 89–91B, lat.  $42^{\circ} 05' N.$ ; long.  $67^{\circ} 49' W.$ ; 110 fathoms, soft mud and sand.

This variety was found on both sides of the 100-fathom line south of Marthas Vineyard near the fortieth parallel, and at a similar depth off the northwest border of St. Georges Bank east of Cape Cod (stations 89–91B).

Specimens from station 921 are incased in cast shells of *Protula*; that from 2177 is accompanied by a tube probably of a sabellid (elastic membrane covered with grains of sand); those from 89–91B are in *Dentalium* shells and one individual in the shell of a small gasteropod. Two small specimens of the typical form were taken at the last-mentioned station.

Without doubt the external peculiarities of this variety are produced by the character of the tubes in which the individuals live; the smooth, elongated body, the shapes of the holdfasts, the length of the introvert, and even the form of the nephridium are clearly adaptations to the life within the slender, smooth-walled tube of *Protula* or shell of *Dentalium*. Moreover, it seems probable that these characteristics are determined anew during the lifetime of each individual by the direct action of the tube or shell upon its occupant.

*Characteristics.*—The body and introvert are long and slender, the introvert of about the same length as the trunk. The trunk is nearly smooth, except near the anterior extremity. Holdfasts lie in a broad zone, which in front extends to the middle of the trunk. It inhabits straight tubes or shells. The ventral muscles when expanded show two long, slender roots. The attachment of the dorsal muscle posteriorly is thicker laterally than in the middle, where it shows a tendency to break apart into several distinct strands. The nephrostome is crescentic with a slender neck.

The introvert, judging from the examination of a few specimens which are mostly somewhat contracted, is of about the same length as the trunk, slender and smooth, except at the base where it is covered with small papillæ. The trunk at its junction with the introvert is covered with very prominent papillæ, in a narrow zone behind which the papillæ decrease rapidly in size. The posterior half of the trunk is smooth, the papillæ being very minute. The holdfasts extend forward to about the middle of the trunk and in some individuals are

extraordinarily variable in shape; the chitinous part of the papilla is usually crescentic and provided with a point projecting forward, but in some individuals the convexity of the crescent extends laterally, or even backward. Double crescents and rings of chitinous material are sometimes found upon the attaching papillæ. These holdfasts therefore appear to be more variable than in other varieties of the species.

There are 16 tentacles. Dark-colored, recurved hooks are scattered over a broad zone separated from the tentacles by a distance about equal to its width. These hooks, though not regularly distributed, may be considered as forming eight or nine irregular rows.

This variety differs internally from others in two or three noticeable respects. The posterior attachment of the dorsal retractor muscle shows a tendency to break into several distinct strands, a fact which is due to the shape of the body wall at the point where attachment is made. The second peculiarity is the shape of the eggs, which are ovoid, translucent, and about 103 by 124 in diameter. The yolk membrane, or zona radiata, is of medium thickness (3.8 or 4) and has distinct pore canals. Finally the crescentic nephrostome joins the nephridium by a somewhat slender neck.

PHASCOLION STROMBI var. CANADENSIS, new variety.

Bay of Fundy. In shells of *Dentalium* and of gasteropods.

Stations 43-46, lat. 43° 06' N.; long. 65° 06' W.; 90 fathoms, fine sandy mud.

Station 47, lat. 43° 10' N.; long. 65° 12½' W.; SE. ½ S. from Cape Sable about 22 miles, 59 fathoms, pebbles and sand. In tubes of *Pectinaria*, tubes of cement, gasteropod shells.

Station 55, mouth of Bedford Basin, 33 fathoms, mud; in *Pectinaria* tubes.

*Type*.—Cat. No. 8582, U.S.N.M.

Stations 82-83, lat. 44° 22' N.; long. 65° 28' W.; Chebucto Light, N. ½ E. 9 miles, 57 fathoms, mud and sand.

Station 103, lat. 44° 02' N.; long. 63° 20' W.; 29¼ miles south of Chebucto Head, 110 fathoms, fine sand and mud.

Stations 106-108, near last. In *Hyalinæcia* tubes.

Station 2506, lat. 44° 26' 00'' N.; long. 62° 10' 00'' W.; 127 fathoms, dark-brown mud.

Station 2697, lat. 47° 40' 00'' N.; long. 47° 35' 30'' W.; 206 fathoms, green mud, black specks.

In certain localities off the coast of Nova Scotia a form of *Ph. strombi* is found with a remarkably short introvert, with a smooth, lustrous skin in the region of the holdfasts, and a tendency of the dorsal retractor to be divided at the posterior attachment into two roots. These characters during the earlier part of my study appeared to be of specific importance, but the examination of many speci-



mens of this form has convinced me that it is to be regarded as merely an unstable variety of a very plastic species.

Although it is exceedingly difficult to estimate accurately the length of the introvert in specimens preserved in all states of contraction, there seems to be no room for doubt that even in the same region off Nova Scotia a form with an introvert shorter than the trunk is found along with the common type. This may be due in part to the fact that these individuals inhabit tubes of *Pectinaria* or of *Hyalinæcia* or the shells of *Dentalium*, which elongates the trunk by compression, and moreover makes the skin in the region of the holdfasts lustrous.

Another peculiarity to which I was at first inclined to attach much importance is the fact that the specimens from certain localities near Halifax either have the dorsal retractor muscle slightly divided at the base, or else it readily separates into two parts in making a dissection. This, however, is not a constant character. Specimens from the same region in most cases have an undivided dorsal retractor.

These peculiarities, although not of sufficient importance to establish a distinct species, do mark the presence of a tendency which may be expressed as a variety or strain, which may be called *canadensis*, the characteristics of which may be briefly summarized as follows, though it should be noted that there is such a mixture constantly occurring between this and the typical variety, *fusca*, as to make it impossible in some instances to make these distinctions: Introvert from one-third to one-half the length of the trunk in extreme cases, but in other individuals equal in length to the trunk. The skin is smooth, except for prominent papillæ near the base of the introvert which are oval, with a small, nipple-shaped tip, or cylindrical. Minute, slender, conical papillæ are found at the posterior end of the body. The region covered with holdfasts is smooth, lustrous, and often iridescent; this region extends forward as far as the middle third of the trunk, which is covered with very minute papillæ but otherwise smooth. The dorsal retractor is distinctly divided at its attachment to the body wall at the posterior end of the trunk. There is less difference in size between the dorsal and ventral retractors than in the typical variety. The nephridium in this form is relatively short, and the nephrostome, as in the variety *gracilis*, has a slender neck.

PHASCOLION STROMBI var. LÆVIS, new variety.

Station 160, 5 miles off Thatchers Island, in 54 fathoms.

Type.—Cat. No. 15109, U.S.N.M.

This variety, which I was at first inclined to regard as a distinct species, lives in tubes constructed of fine pebbles of different sizes firmly cemented together and consisting of two parts, namely, that

covering the trunk, similar to the tube of the variety *tubicola*, and a slenderer, extremely long, tapering portion that covers the introvert. The latter part of the tube, like the former, contains minute pebbles and particles of mud that are graduated in size, becoming finer toward the distal end and embedded in a parchment-like material, which alone forms the small anterior extremity of the tube.

This variety, of which I have examined only one complete specimen, is characterized externally by having an unusually long, slender, smooth, and light-colored introvert (pl. 60, fig. 13) that is somewhat sharply marked off from the thicker, darker-colored trunk, which at the posterior end is sharply truncated and of a light brown color.

The length of the trunk of the single entire specimen is about  $6\frac{1}{2}$  mm.; the introvert is about twice as long; the greatest diameter of the trunk is about 2 mm., of the introvert about seven-eighths mm. The papillæ of the anterior part of the trunk are small, inconspicuous, oval elevations; and the rest of the trunk is almost smooth, except that minute epidermal organs are scattered over the region immediately in front of the extremely small, crescentic holdfasts which occupy a zone very near the posterior end of the body.

The introvert is smooth, except that minute papillæ are scattered over its posterior third.

The longitudinal muscle layer is continuous and lustrous. The dorsal retractor muscle (fig. 11) is much larger than the ventral, and is attached at the posterior end of the

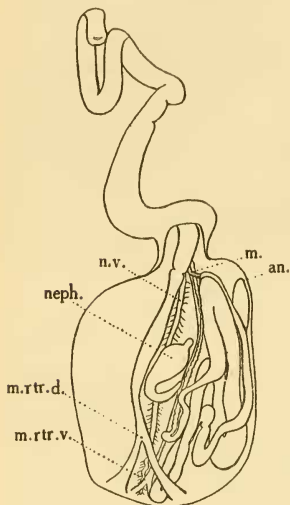


FIG. 11.—DISSECTION OF PHASCOLION STROMBI VAR. LEVIS.  $\times 6$ . *an.*, ANUS; *m.*, SUSPENSORY MUSCLE OF INTESTINE; *m. rtr. d.*, DORSAL RETRACTOR MUSCLE; *m. rtr. v.*, VENTRAL RETRACTOR MUSCLE; *neph.*, NEPHRIDIUM; *n.v.*, VENTRAL NERVE CORD.

cœlum by two widely separate roots,<sup>1</sup> each with a broad attachment. The two roots of the dorsal muscle unite at a distance from the

<sup>1</sup> Since making the dissection on which this description was based, I have frequently found that in certain individuals of *Ph. strombi* there is a marked tendency for a really undivided dorsal retractor to split in two at the base under the slightest stress, so that in dissection it is difficult to ascertain whether the dorsal retractor is actually divided or single. Hence too much taxonomic weight must not be placed upon this anatomical difference. Accordingly, with the small amount of material at hand, I am inclined, finally, to describe this form as a variety of *Ph. strombi*, though the tube which it constructs and its long, smooth introvert, not to mention the dorsal retractor muscles, are distinctly peculiar; for *Ph. strombi*, particularly of the tube-making variety, is very common in the region where this specimen was found, and it would be expected that aberrations or mutations would occur, and it is such that I believe *Ph. strombi* var. *levis* to be.

posterior end of the body equal to about one-fourth the length of the trunk. The ventral muscle is slender and inconspicuous. It is attached by two cylindrical roots, one on each side of the posterior end of the nerve cord.

The long, slender esophagus joins a wide intestine of about six loops extending backward and forward. A prominent strand of muscle fibers extends from the anterior intestinal loops into the region of the introvert, and less conspicuous strands elsewhere hold the intestine to the body wall. The single (right) nephridium is large, and has a prominent nephrostome. The nerve cord is a relatively wide band.

#### MODIFICATIONS IN THE SOUTH.

The number of local varieties of this species probably will be found to be even greater when the southern part of its range is more thoroughly explored. A specimen from off Cape Charles, Virginia (station 2003, 641 fathoms), is typical in internal features in all respects, but externally it is remarkable for its peculiar dark greenish-gray color. It has a thick integument covered with prominent papillæ, and an unusually distinctly marked anus. Except for the peculiar greenish-gray hue it resembles the variety *tubicola* from the region of Cape Ann. Its shape indicates that it lived in a tube of cement.

Other specimens from the same southern region, that is, from the fortieth parallel southward to Cape Hatteras, have a noteworthy internal peculiarity, namely, the posterior attachment of the ventral retractor does not lie behind the posterior end of the nerve cord, as in other varieties of this species, but beside it to the left, thus showing a more prominent asymmetry in the internal organization than in any other variety of the species.

Externally these specimens from different southern localities differ much. Those from the shells of *Dentalium solidum* (station 2733, 944 fathoms, off Cape Charles; station 2207, 1,071 fathoms, just south of the fortieth parallel) have a thin, smooth skin of orange brown color. Those from the gasteropod *Sipho pygæus* (station 898, 300 fathoms, off Norfolk, Virginia) have a smooth, whitish skin and an external appearance like those described as the variety *alba*.

The crowding aside of the extremity of the retractor in reference to that of the nerve cord has made a still further modification in certain individuals inhabiting the shells of *Dentalium solidum*, in that the attachment of the ventral retractor is undivided; this, however, is not true of the specimens from the shells of *Sipho pygæus*. Selenka (1883) likewise found in a specimen from the West Indies, which he

describes as *Ph. tubicola* (Verrill) (= *Ph. strombi*), that the ventral retractor has a single root attached at the left of the posterior end of the nerve cord, as is shown by his figure 82. The three individuals from the West Indies which he examined, moreover, lived in tubes of cemented mud and sand. As stated above, I have found this peculiarity in specimens from the shells of *Dentalium solidum*, so that it would appear to be a southern characteristic or tendency not determined by the nature of the shell or tube which the worm inhabits, but hereditary.

PHASCOLION ALBERTI Sluiter.

This form, which Sluiter (1900) describes, apparently differs only in external features from *Ph. strombi*, which it is like in habits and in the arrangement of its retractor muscles. The length of the introvert is described as two-thirds that of the trunk, in which respect it resembles many of the specimens of *Ph. strombi* from the same general region (vicinity of Nova Scotia), which show a tendency to have a shorter introvert than elsewhere. The papillæ of the anterior and middle parts of the trunk, however, rather than of the posterior end, bear chitinous denticles pointing forward, whereas those near the posterior extremity are capped with a perforated, oval crown of chitinous material. The ventral nerve cord is prolonged beyond the attachment of the ventral retractors, passing between the two roots.

This form was taken in considerable abundance by the Prince of Monaco at his station 161, off Newfoundland, lat. 46° 04' 40'' N.; long. 49° 02' 30'' W., in 1,267 meters, and off Cape Finisterre in 1,674 meters. It has not been found, to my knowledge, by any expedition from the United States that has explored the same general region.

Genus DENDROSTOMA Grube.

This genus includes a few species which are distinguished from their natural allies of the genus *Phascolosoma* by the tree-like branching of their tentacles, which are ramifications of from four to eight main trunks. The longitudinal muscle layer is continuous, the nephridia free, and the intestinal coil unattached behind. The trunk in most species is short and thick. The short introvert is provided with hooks or spines, except in *D. peruvianum* Collin. The Polian vessel (contractile tube) is provided in most cases, though not in *D. blandum* Selenka and De Man, with numerous caeca. These species inhabit tropical seas.

Of the six recorded species *D. pinnifolium* Keferstein has four retractor muscles, the others have two. *D. pinnifolium* Keferstein, as well as *D. alutaceum* Grube, is found in the West Indies (St. Thomas, Selenka); *D. peruvianum* Collin off the Peruvian coast; *D. blandum* Selenka and De Man, *D. signifer* Selenka and De Man, and *D. spinifer* Sluiter in the western part of the Pacific Ocean.

Selenka (1883) called attention to the fact that this genus includes species which would naturally be included within the genus *Phascolosoma*, but which may be conveniently segregated until our knowledge of the affinities of the various species of this larger genus is more complete.

*DENDROSTOMA ALUTACEUM* Grube.

Station 2280, off Cape Hatteras, lat. 35° 21' N.; long. 75° 25' 30' W.; 16 fathoms, gray sand and broken shells.

Cedar Keys, Florida, on coral, 1 fathom.

Dry Tortugas, Florida.

Key West, Florida.

Body pear-shaped (fig. 12 and pl. 59, fig. 9), with the greatest width near the posterior end, which terminates in a papilla-like elevation.

Introvert cylindrical; the anterior half is smooth, behind which there is a wide (2 mm.) band of prominent, recurved hooks. The cuticular covering the base of the introvert is divided into rectangular blocks. The surface of the trunk is marked with fine transverse furrows, visible only with a lens, separating narrow ridges of cuticula which show minute pits. The body is brownish-flesh-color, the cuticula being suffused with white, so that the general effect in alcoholic specimens is grayish-brown.



FIG. 12.—*DENDROSTOMA ALUTACEUM*.  $\times 8\frac{1}{2}$ . an, ANUS.

The numerous tentacles are grouped in six tree-shaped bunches, long, slender, and grooved upon their oral surfaces. The color of the tentacles, like the rest of the introvert, is light yellowish-brown, but individual tentacles are flecked with spots of dark brown pigment upon the oral surface, generally both in the middle and near the tip.

The longitudinal muscles of the body wall form a continuous layer; the circular muscles are divided into distinct bundles, which anastomose. The breaks between these bundles of circular muscle fibers give rise to transverse furrows upon the surface of the body.

The two large, ventral retractors (fig. 13) have their origin in wide attachments at the posterior end of the middle third of the length of the trunk. The pair of nephridia are very long, and attached to the body wall slightly behind the anus. The esophagus is slender, and the large coil of the intestine nearly fills the posterior part of the cavity of the trunk. A spindle muscle is inserted in the body wall immediately behind the anus, and muscle strands run from the intestinal coil to each side of the wall of the body slightly in front of the origin of the retractor muscles. The esophagus bears upon the dorsal surface at its

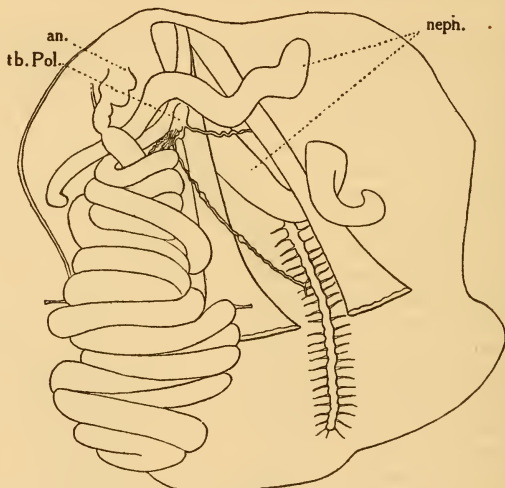


FIG. 13.—DISSECTION OF *DENDROSTOMA ALUTACEUM*.  $\times 10\frac{1}{2}$ . *an*, ANUS; *neph*, NEPHRIDIUM; *tb. Pol*, POLIAN TUBULE.

posterior end an enlargement of the Polian canal in the form of a small sac (fig. 13), from which a bunch of fine blind tubes run backward into the intestinal coil, and isolated tubes extend to the ventral side of the body wall. These tubes when stretched become straight, but, when the tension is relaxed, they take the form of a fine spiral. Varicosities occur at intervals in the larger tubules. Two faintly pigmented eye spots are visible in one of the larger specimens. The cerebral ganglion as seen from above with a low power has nearly a circular contour; a prominent, crescentic cerebral organ extends in front of it. No nuchal organ was observed.

Genus *PHYSCOSOMA* Selenka, 1897.*Phymosomum* QUATREFAGES, 1865.*Phymosoma* SELENKA, BÜLOW, and DE MAN, 1883.

Longitudinal muscle layer of the body wall in most species discontinuous (continuous in *Ph. capitatum*, new species). Tentacles in a single row, not encircling the mouth, but situated dorsal to it along a crescent opening dorsad. Body covered with papillæ. Hooks, arranged in rings, usually present (not in *Ph. antillarum* Grube and Örsted). Usually four retractors, the dorsal and ventral of each side tending to fuse. Contractile tube in most species without cæca (not in *Ph. antillarum* Grube and Örsted). Eye-spots generally occur (not in *Ph. capitatum*).

*PHYSCOSOMA VARIANS* (Keferstein).*Phascolosoma varians* KEFERSTEIN, 1865.*Phascolosoma perlucens* BAIRD, 1868.

This species (pl. 62, fig. 18) is abundant at Key West and at the Dry Tortugas, Florida, and is also found at other points off the southern coast of that State, as at Cape Florida and Key Vaccas. It is abundant among the West Indies (Keferstein, 1866; Selenka, 1883), at the Bahamas (Shiple, 1890), Bermudas (specimens collected for me through the kindness of Prof. E. L. Mark), and occurs also at Ascension Island in the South Atlantic (W. H. Brown, Eclipse Expedition to West Africa, 1889).

The following is a translation of Keferstein's description as given by Selenka (1883):

Trunk three to four times as long as thick, introvert as long as or longer than the trunk. Skin yellowish, thin, somewhat iridescent, with many scattered, large, dome-shaped, rounded papillæ, which are darkly pigmented on the dorsal side of the animal (a dark ring with a light center) and are often grouped together there into spots, giving a marbled appearance. The diameter of the papillæ is 0.20–0.22 mm. The posterior half of the introvert resembles the trunk in appearance, and the anus is not conspicuous; the anterior half, on the other hand, bears only small papillæ, appears accordingly rather smooth, and is often pigmented with brown, usually transverse, bands. It carries numerous closely-set rows of hooks of very variable number (12–90), which, accordingly, in many cases cover only the most anterior part, but often the whole anterior half, of the introvert. The hooks are very characteristic, broadly leaf-shaped, with the upper point bent to a right angle, and with large, rounded, accessory projections on the inner edge. Between the rows of hooks are hook-papillæ rather regularly arranged. On the anterior part of the introvert, immediately behind the tentacles, is an entirely smooth zone.

The 20-28 short tentacles, standing in two lateral rows, do not encircle the mouth, but are situated on the dorsal side of it, encircled by a low collar of integument opening dorsally.

The musculature is strong; the longitudinal muscle layer is split into about 30 (26-32) anastomosing bands, and the circular muscle layer also tends to form bands. Four strong retractors, of which the ventral are attached in the posterior, the dorsal in the anterior part of the middle third of the trunk; and those of the same side are united only in the anterior part of the introvert. Two large eye-spots. Intestinal coil with few whorls, with a complete columellar muscle and a single fastener ventral to the esophagus and the first whorl. Rectum of medium length. Contractile tube simple, only 0.24 mm. thick. Nephridia very long, fastened by a mesentery along the anterior third. Eggs (0.12 mm.) with a thin yolk membrane pierced with fine pore canals. Trunk 35 mm., introvert 42 mm.

The structure of this very variable species has been well described by Shipley (1890).

PHYSCOSOMA ANTILLARUM (Grube and Örsted).

*Phascolosoma fuscum* KEFERSTEIN, 1862.

*Phascolosoma nigriceps* BAIRD, 1868.

Key West, Florida, cavities in rocks between tides (Henry Hemphill, 1885). Five specimens.

This species has been found among the West Indies at Muriel, Cuba (U. S. Nat. Mus., Palmer and Riley), St. Croix (Grube and Örsted), St. Thomas (Keferstein), Barbados (Stuttgart Museum, Selenka; U. S. Nat. Mus., Worthing, Barbados, on reef, (H. M. Lefroy) and Jamaica (Baird); off the adjacent mainland of Colombia, Sabanilla, and Venezuela (U. S. Nat. Mus., *Albatross*, 1884), at Puerto Cabello (Grube), and Pernambuco and Goyanna, Brazil (U. S. Nat. Mus., A. W. Greeley). In the Pacific, it has been found on the coast of Costa Rica at Puntarenas (Grube and Örsted) and on the coast of Chile (Baird).

The following description is based largely on Keferstein's account, as given by Selenka (1883), which agrees closely with the facts as I have found them:

*Distinctive features.*—Introvert one-half to one-third the length of the trunk (pl. 62, fig. 20), which in a partially contracted specimen is four or five times as long as thick (pl. 62, fig. 19). The thick skin is everywhere covered with prominent, flat, dark-brown papillæ between which the whitish or yellowish skin appears. Papillæ at the posterior end of the trunk and especially at the base of the introvert are large, rough, and dark-colored, forming at the anterior extremity black plates separated only by narrow fissures. On the introvert the papillæ are further separated and are conical with a sharp apex.



In the front part of the introvert a smooth zone is sharply marked off; and a small, upright collar, split dorsally, lies at the base of the numerous (50–80) long, thread-shaped tentacles, which are often transversely striped with alternating rings of brown and white. The longitudinal muscle layer consists of separate, frequently anastomosing bands (30 in the middle of the trunk, 20 in the front, but subject to much variation). Four retractor muscles arise near one another in the second third of the trunk, but immediately unite on each side to form a single, lateral muscle. Brain with distinct eye spots. Intestinal coil of few (about 20) whorls. Rectum long. A columellar muscle fastens the intestine in front of the anus and at the posterior end of the trunk. The contractile vessel on the esophagus and on the first intestinal coil has many finger-shaped diverticula terminating in tubular cæca. Nephridia very long (over one-half the length of the trunk) and attached along almost the whole length to the body wall by a fold of peritoneum.

One of the specimens from Key West is unusually large, the trunk being 47 mm. in length. The usual length of the trunk is about 30 mm.; introvert 18 mm.

**PHYSCOSOMA CAPITATUM, new species.**

Station 2231, lat. 38° 29' N.; long. 73° 09' W., east of Cape May; 965 fathoms, gray ooze; temperature at bottom, 36.8° F.

Station 2103, lat. 38° 47' 20'' N.; long. 72° 37' W., east of Cape May; 1,091 fathoms, Globigerina ooze; temperature at bottom, 39° F.

Station 2685, lat. 39° 35' N.; long. 71° 02' 30'' W., south of Marthas Vineyard; 1,137 fathoms, green mud with white specks; temperature at bottom, 37.9° F.

Station 2029, lat. 39° 42' N.; long. 70° 47' W.; south of Marthas Vineyard; 1,168 fathoms, gray mud; temperature at bottom, 38½° F.

*Type*.—Cat. No. 4067, U.S.N.M.

Station 2093, lat. 39° 42' 50'' N.; long. 71° 01' 20'' W., south of Marthas Vineyard; 1,000 fathoms, foraminifera, sand and mud; temperature at bottom, 39° F.

Station 2192, lat. 39° 46' 30'' N.; long. 70° 14' 45'' W., south of Marthas Vineyard; 1,060 fathoms, gray ooze; temperature at bottom, 38.6° F.

Station 2572, lat. 40° 29' N.; long. 66° 04' W., southeast of Georges Bank; 1,769 fathoms, gray ooze; temperature at bottom, 37.8° F.

Station 2531, lat. 40° 42' N.; long. 66° 33' W.; southeast of Georges Bank; 852 fathoms, gray mud; temperature at bottom, 38.4° F.

Station 2530, lat. 40° 52' 30'' N.; long. 66° 24' W., southeast of Georges Bank; 956 fathoms, gray ooze; temperature at bottom, 38.4° F.

Station 2528, lat.  $41^{\circ} 47' N.$ ; long.  $65^{\circ} 37' 30'' W.$ , east of Georges Bank, 677 fathoms, brown sand; temperature at bottom,  $38.7^{\circ} F.$

Station 2072, lat.  $41^{\circ} 53' N.$ ; long.  $65^{\circ} 35' W.$ , south of Cape Sable, east of Provincetown, Massachusetts; 858 fathoms, gray mud; temperature at bottom,  $39^{\circ} F.$

The range of this species extends from the latitude of Cape Cod (station 2072) southward as far, at least, as that of Cape May (station 2231). It is found at depths varying from 677 to 1,769 fathoms. No other species of this genus, with the exception of *Ph. lovénii* Koren and Danielssen, has been found as far north, the most of the species being inhabitants of tropical or subtropical waters. The temperature of the water from which the specimens were taken in summer and autumn was  $36^{\circ}$ – $39^{\circ} F.$

This species differs from others of this genus in that the longitudinal muscle layer is entirely continuous, the almost universal condition in *Phascolosoma*. The eggs are spherical, as in *Phascolosoma*, and there are no eye-spots visible upon the surface of the cerebral ganglion; whereas in most species of *Physcosoma* the eggs are said to be elliptical and flattened, and eye-spots are present. The peculiar arrangement of the tentacles, however, dorsal to the mouth in a crescent opening dorsad (pl. 51, fig. 15), places this species in the genus *Physcosoma*.

*Distinctive features.*—Trunk ovate with thick, rough, dark-brown integument, thickly studded at the posterior end with broad, yellowish-brown and hence conspicuous papillæ, which elsewhere are thinly scattered over the trunk (pl. 61, fig. 16; pl. 62, fig. 21).

Introvert cylindrical, shorter than the trunk, which it resembles in the color and texture of the skin, except in the anterior fourth, which is sharply contrasted with the rest by having a light orange color and thin walls, forming an oval "head" (pl. 62, fig. 21). The main part of the introvert is covered with light yellowish-brown papillæ, which are about twice as large at the proximal as at the distal end of this region. Papillæ of smaller size extend over the base of the orange-colored "head," around which about 35 rows of minute hooks (pl. 61, fig. 16) extend. There are 14 tentacles, arranged in the characteristic fashion of *Physcosoma*, dorsal to the mouth in a crescentic row opening dorsad (pl. 61, fig. 15). A collar consisting of an annular fold of integument surrounds the anterior part of the "head," immediately behind the mouth and tentacles.

There are four short retractor muscles of which the ventral, which are much the larger, are attached near the posterior end of the trunk; the slender, dorsal pair are attached slightly in front of the others, and unite together posterior to their union with the ventral pair. There are no eye-spots. The eggs are spherical, small, and transparent, covered with a yolk membrane pierced with distinct pore canals.

The size of the larger specimens, extended, is: trunk 16 mm. long and 7 mm. thick; introvert 12 mm. long and 1.5 mm. thick. Still larger specimens have a trunk 17 mm. long and 9 mm. thick, and 19 mm. by 7 mm.

The integument of the posterior end of the trunk in some specimens is so thick as to suggest a shield like that of *Aspidosiphon*, but this is not a constant characteristic.

The papillæ are generally low, flat domes, capped by a central rounded protuberance.

The nerve cord is prominent, and is held to the ventral wall of the introvert by a mesentery; the lateral nerves are inconspicuous. A long esophagus (fig. 4) joins an intestinal coil of about 20 whorls held by a prominent spindle muscle attached posteriorly to the tip of the body wall. A muscle strand extends from the middle of the esophagus forward to the junction of the two ventral retractors, in front of which the anterior part of the esophagus is fastened to the retractors by a fold of peritoneum. A

short, simple Polian tube or contractile vessel lies over the united portion of the pair of dorsal retractors.

The nephridia (fig. 14) are attached to the body wall nearly opposite the anus. They are of medium length.

This species varies much in regard to the position of the points of attachment of the retractor muscles to the body wall. Thus in one specimen both pairs were attached near together near the middle of the trunk. In a small, young specimen the ventral retractors have the usual attachment near the posterior end of the body, whereas

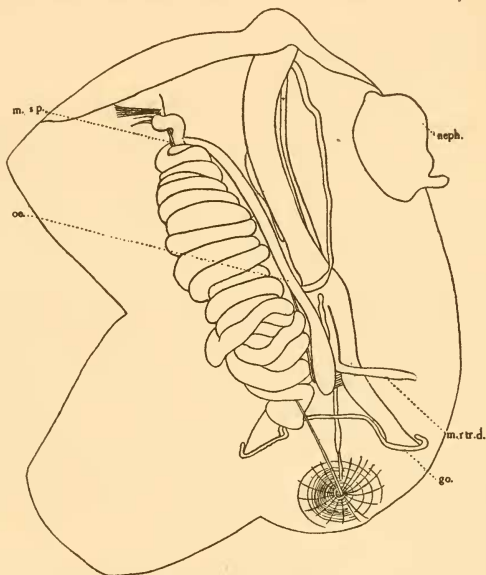


FIG. 14.—DISSECTION OF *PHYSICOSOMA CAPITATUM*.  $\times 4\frac{1}{2}$ . *go*, REPRODUCTIVE ORGAN; *m. rtr. d.*, DORSAL RETRACTOR MUSCLE; *m. sp.*, SPINDLE MUSCLE; *neph.*, NEPHRIDIUM; *es.*, ESOPHAGUS.

the slender dorsal muscles are joined to the body wall much further forward than in the individual which I have figured (fig. 14), and underneath the nephridia. In general, in the few specimens which I have dissected, the position of the attachment of the dorsal retractors varies from about the posterior end of the first third of the trunk backward to the posterior end of the third quarter.

The resemblance of this species to *Phascolosoma* has been noted above. Like *Phascolosoma scutigera* Roule and *Ph. approximatum* Roule which it resembles closely in its proportions, its musculature and other respects, it suggests also the genus *Aspidosiphon*, though to a less extent than the former of the two species mentioned. A posterior shield is distinctly suggested in some specimens by the thickening of the integument of the posterior end of the trunk and, to a less extent, at the anterior extremity.

It seems not impossible that some of the deep-sea sipunculids described by Roule (1907) as species of *Phascolosoma* belong rather in *Physcosoma*, a genus which Roule apparently does not recognize as including several species originally described as *Phascolosoma* (as, for instance, *Ph. agassizii* Keferstein, *Ph. varians* Keferstein). Thus Roule's *Phascolosoma vulgare* de Blainville var. *multipapillosa*, so far as one can judge by his figure (fig. 89) and very brief description in which he compares this form to *Phascolosoma* (= *Physcosoma*) *agassizii* Keferstein, apparently resembles *Physcosoma*. No statement is made as to whether its longitudinal muscle layer is continuous, as in *Phascolosoma vulgare*, or discontinuous as in *Physcosoma agassizii*. Superficially, and as regards its retractor muscles, it resembles *Physcosoma capitatum*. The one individual of this "variety *multipapillosa*" came from Mogador, West Coast of Africa, and a depth of 1,050 meters. The incomplete crown of tentacles in *Phascolosoma approximatum* Roule, suggests that possibly this also is a species of *Physcosoma*.

#### Genus ASPIDOSIPHON Grube.

Individuals of this genus have a distinct shield in front of the anus and one at the posterior extremity of the body. The introvert is much slenderer than the trunk, with which it is connected ventral to the anal shield. Rings of hooks are found in most species upon the introvert. The longitudinal muscle layer is either continuous or discontinuous. Only the ventral retractors are present, and they are fused more or less completely.

Most of the species of *Aspidosiphon* that have been described inhabit the Pacific and Indian Oceans. In the Atlantic, *A. armatus* Koren and Danielssen and *A. mirabilis* Théel occur off the coast of Norway and Sweden, *A. mülleri* Diesing is found with *A. venabulum* Selenka and Bülow off the west coast of Africa (Fischer, 1894), and

in the Bay of Biscay and the Azores (Sluiter, 1900), and *A. speculator* has been taken at St. Vincent (Cape Verde Islands). *A. truncatus* Keferstein, which occurs both at Panama (Keferstein, 1866) and Mauritius (Selenka, 1883), is also likely to be found in the Atlantic.

*ASPIDOSIPHON PARVULUS*, new species.

Station 2280, off Cape Hatteras, lat. 35° 21' N.; long. 75° 21' 30'' W.; 16 fathoms, gray mud and broken shells. Two specimens. With *Phascolosoma verrillii* Gerould and *Dendrostoma alutaceum* Grube.

*Type*.—Cat. No. 15118, U.S.N.M.

The larger of the two specimens noted above measures: trunk 4 mm., introvert 2.5 mm. The smaller: trunk 3 mm., introvert 1.5 mm. The introvert of both specimens is partially retracted, though that of the larger specimen is almost completely extended.

The most distinctive features are: the diminutive size; introvert shorter than the trunk (pl. 61, fig. 17) and beset with numerous, minute, slender hooks; anterior shield irregularly covered with prominent spines; posterior shield divided by radial furrows into rounded or squarish plates; the longitudinal muscle layer continuous.

The trunk is short and thick, the thickness being about one-half the length in a slightly contracted specimen. The color is light yellowish- or grayish-brown; the anterior and posterior shields, which are prominently marked off, are deep yellowish-brown. The anterior shield is covered with prominent spines, of which those along the margin are sharply conical, those in the center flat. The posterior shield is divided by radial and circular furrows into squarish or rounded, partially separate plates, and at its center is a knob-shaped elevation. The entire shield is covered with a minutely granular embossing, visible with a magnification of 17 diameters (pl. 61, fig. 17).

The trunk is smooth, but is covered with flat epidermal organs with a circular outline and a central depression. They are visible with a hand lens only on the posterior part of the trunk in front of the posterior shield, where they are largest. They gradually diminish in size from that region forward, and are visible on the anterior half of the trunk only with a magnification of 60 diameters or more. The

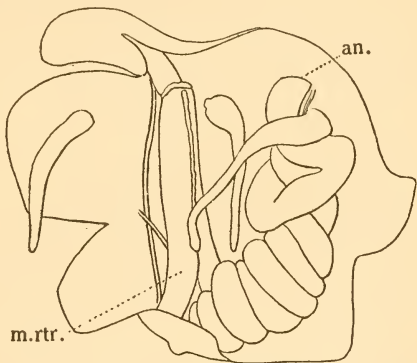


FIG. 15.—DISSECTION OF *ASPIDOSIPHON PARVULUS*.  $\times 17\frac{1}{2}$ .  
an, ANUS; m.rtr, RETRACTOR MUSCLE.

surface of the trunk in the larger specimen is blocked off into rectangular elevations by the contractions of the underlying muscles.

The introvert, which is shorter than the trunk, is cylindrical, and covered with exceedingly minute, slender, recurved hooks, which can not be seen easily with a magnification of less than 60 diameters.

The posterior end of the retractor muscle (fig. 15) is divided, and the two roots (representing the right and left ventral retractors) are inserted on each side of the posterior shield. A muscle strand extends to the body wall from the retractor immediately in front of the angle between the diverging roots. The longitudinal muscles of the body wall form a continuous layer. The long, slender nephridia are attached by a fold of peritoneum to the body wall. The intestine makes a coil of about 10 wide turns, and is supported by a very strong spindle muscle. The ventral nerve cord projects prominently into the body cavity.

This form somewhat resembles *A. mirabilis* Théel of the west coast of Norway and Sweden, but, aside from size, it differs from it in the smoothness of the trunk, the presence of prominent spines on the anterior shield, the attachment of the nephridia by folds of peritoneum, and other less marked features.

ASPIDOSIPHON SPECIOSUS, new species.

Key West, Florida, shore (?). One specimen.

*Type*.—Cat. No. 16320, U.S.N.M.

Station 2336, off Havana, lat.  $23^{\circ} 10' 48''$  N.; long.  $82^{\circ} 18' 52''$  W.; 157 fathoms, coral bottom. One specimen.

Station 2758, east of Brazil, lat.  $6^{\circ} 59' 30''$  S.; long.  $34^{\circ} 47'$  W.; 20 fathoms, broken shells; temperature at surface and bottom,  $79^{\circ}$  F. One specimen.

*Distinctive features*.—Introvert nearly or quite as long as the trunk (pl. 62, fig. 22). About 110 rows of fine, single-pointed hooks (fig. 16) on the first fifth of the introvert. Introvert and middle of the trunk smooth. Ends of the trunk covered with polygonal elevations. Both shields furrowed (pl. 62, fig. 22). Longitudinal muscle layer discontinuous. A transverse septum stretches across the cœlom in front of the anus and the nephridia. Ventral retractor muscles fused into one. No eye-spots.

The trunk of the specimen from Key West is 40 mm. in length, the introvert 38–40 mm. in length. The spines on the posterior part of the introvert are exceedingly fine and the introvert is smooth. The anterior and posterior ends of the trunk are covered with polygonal or squarish elevations of a dark-brown color on a grayish field. The middle portion (nearly one-half the length) of the trunk is smooth and of a yellowish-brown color. The shields are dark brown and furrowed. The anterior shield is oval, with its long axis transverse, with 18 short and long furrows at its posterior edge, converging as

they run forward toward the base of the introvert. The posterior shield has 22–26 radial furrows, of which only about 15 reach the rounded elevation at the center. The edges of the posterior shield, by the contraction of the circular muscles in front of it, sometimes project above the general surface of the body, so that the radially ribbed, circular shield, rising like a flat dome from the cylindrical trunk in a contracted specimen, suggests an extremely ornamental roof of a Chinese pagoda.

The longitudinal muscle layer consists of about 46 flat, plate-like bands, which anastomose under the anal shield and in the region of the nephridia. The single retractor muscle formed by the fusion of the two ventral retractors is attached to the body wall by two roots, one on each side of the nerve cord at a considerable distance (= two-sevenths the length of the trunk) in front of the posterior shield.

A prominent transverse septum stretches across the cœlom immediately in front of the anus and the openings of the nephridia, thus isolating a small space beneath the anterior shield. The nephridia are not connected with it. They are each attached to the body wall by a short fold of peritoneum extending along about one-fifth or one-fourth of the length of the nephridium. The nephrostome is a prominent fold with a heart-shaped contour connected with the rest of the nephridium by a slender neck. The intestinal coil of many whorls is held to the middle of the posterior shield by a large columellar muscle. There is a large, oval diverticulum upon the rectum near the anus. The rectum is held by a longitudinal fold of peritoneum containing muscle fibers.

This species resembles *A. klunzingeri* Selenka and Bülow from the Red Sea.

#### Genus SIPUNCULUS Linnæus.

This genus includes, in general, large sipunculids, which are found in all seas from the polar to the equatorial regions. The trunk is without papillæ and the introvert without hooks. A flat tentacular fold surrounds the mouth, and its margins in some species are drawn out to form more or less distinct tentacles. The individual tentacles contain a network of blood vessels and not three longitudinal passages as in *Phascolosoma*. A median-dorsal unpaired epithelial tube opens upon the surface of the head immediately behind the tentacular fold, and leads backward to a cerebral sense organ anterior and ventral to the brain. The esophageal connectives do not surround the attachments of the retractor muscles to the head, as in most sipunculids, but lie behind and beneath these attachments. There are usually two contractile tubes of the vascular system. One or



FIG. 16.—HOOKS FROM INTROVERT OF ASPIDOSIPHON SPECIOSUS. X 290.

more cæca are found on the rectum. Eggs spherical. The prototroch cells of the embryo form an embryonal envelope, which is cast off with the vitellin membrane (*S. nudus*).

SIPUNCULUS NUDUS Linnæus.

This cosmopolitan species occurs in the Mediterranean Sea, on the Atlantic coast of Spain and of France, the North Sea, Panama (Keferstein, 1866), the southern coast of the United States, and also the coast of Malacca (Selenka, 1883) and Loyalty Islands (Shipley, 1899).

A specimen of this species from Key West, Florida, and others from Beaufort, North Carolina, resemble closely those from the English Channel (Roscoff, Finistère), with which I have compared them. Another specimen from Key West, probably of this species, shows some of the peculiarities ascribed to *S. titubans* Selenka and Bülow. That is, its nephridia are attached for nearly one-half their length, whereas in specimens of *S. nudus* (from Roscoff) they are attached for one-fourth to one-fifth their length (as in the other specimen from Key West that I have examined), and are described by Selenka (1883) as free. The specimen appears to be pigmented also, though how much of its present hue may be due to discoloration through desiccation can not be determined. Otherwise it is a typical *S. nudus* with 31-32 longitudinal muscle bands, ventral retractors arising from longitudinal muscles 2-6, dorsal retractors from 7-11. A specimen from Beaufort, North Carolina, likewise has its nephridia attached for two-fifths of their length, though it is not different otherwise from *S. nudus* from the English Channel. Inasmuch as the length of the nephridia varies enormously in the living animal according to conditions of expansion or contraction, undue weight has probably been placed upon this point by Selenka in the determination of species.

SIPUNCULUS TITUBANS Selenka and Bülow.

Although the scope of this paper does not include the description of West Indian sipunculids not also found off the coast of the United States, it may be well to call attention to certain specimens in the National Museum from this region which are probably to be identified as *S. titubans* Selenka and Bülow, but which suggest that this species may be only a local variety of *S. nudus* with no very constantly correlated variations from the widespread form.

Thus a specimen from Jamaica has the nephridia attached through half their length as in *S. titubans*, but has 30 longitudinal muscle bands as in *S. nudus*, not 26 or 27 as in *S. titubans*<sup>1</sup>; specimens from Trinidad have 27-28 longitudinal muscles, an intermediate condition

<sup>1</sup> Selenka and Bülow's original description of *S. titubans* says 26; Fischer's 26 or 27 in front, 32 behind.



between *S. nudus* and *S. titubans*, and free nephridia as in *S. nudus*. In all these specimens the four retractors arise in the same zone, the ventral having their origin from longitudinal muscles 2-4, the dorsal from 9-13. (See Selenka's description: 3-5 ventral, 8-13 dorsal. Fischer's, 1894: 3-5 ventral, or 1-5 ventral, and 9-12 dorsal or 8-13 dorsal.) A spindle muscle is present as in *S. nudus*. Nephridia open between longitudinal muscle bands 4-5, as in *S. nudus* and *S. robustus*.

These specimens are unpigmented except at the anterior extremity of the trunk, where the longitudinal ridges are inconspicuously marked for 10 mm. or less with longitudinal rows of small circular bluish-brown spots tending to become confluent. The trunk of the specimen from Jamaica is 65 mm. long. The Trinidad specimens measure: Trunk 110 mm., introvert (narrow papillated part only, not the whole region in front of the anus) about 15 mm. Another: Trunk 70 mm., introvert 10 mm.

It will readily be seen that these specimens suggest that *S. titubans* is a variable form closely resembling *S. nudus* and *S. robustus* Keferstein, from which, in some cases at least, it can hardly be distinguished.

*S. titubans* was originally described by Selenka and Bülow (1883) from a specimen from Puntarenas on the Pacific coast of Costa Rica. Specimens in the Hamburg Museum described by Fischer (1894) are from St. Jose di Guatemala (Pacific coast of Guatemala) and Madagascar; and a variety of the species from Accra, West Africa, is also described by Fischer. According to Selenka it has been found in the Barbados and is common in the Pacific, especially at Uwea (Wallis Island), Opalu (Samoa), Pelew Islands, Palaos, Amboina, Timor, and Lyly Islands.

SIPUNCULUS PRIAPULOIDES Koren and Danielssen var. AMERICANA, new variety.

*Phallosoma priapuloide* (LEVINSEN), 1882 and 1883.

Type.—Cat. No. 1379, U.S.N.M. From station No. 2709.

Specimens were taken from the following localities off the coast of the United States:

Station 2530, southeast of Georges Bank, lat. 40° 53' 30'' N.; long. 66° 24' W.; 956 fathoms, gray ooze; bottom temperature, 38.4° F.

Station 2709, south of Georges Bank, lat. 40° 07' N.; long. 67° 54' W.; 866 fathoms, brown mud.

Station 2217, lat. 39° 47' 20'' N.; long. 69° 34' 15'' W.; 924 fathoms, gray mud; temperature at bottom, 38.1° F.

Station 2235, off Cape May and Sandy Hook, lat. 39° 12' N.; long. 72° 03' 30'' W.; 707 fathoms, green mud; temperature at bottom, 38.8° F.

Station 2018, off Cape Charles, Virginia, lat.  $37^{\circ} 12' 22''$  N.; long.  $74^{\circ} 20' 04''$  W.; 788 fathoms, blue mud; temperature at bottom,  $39^{\circ}$  F.

Station 2731, off Cape Charles, Virginia, lat.  $36^{\circ} 45'$  N.; long  $74^{\circ} 28'$  W.; 841 fathoms, gray ooze.

Station 2677, off Charleston, South Carolina, lat.  $32^{\circ} 39'$  N.; long.  $76^{\circ} 50' 30''$  W.; 478 fathoms, green mud; bottom temperature,  $39.3^{\circ}$  F.

An allusion to this form was made by Verrill, 1885, page 23, in his report of the *Albatross* explorations. Among the undetermined species of *Gephyrea* he mentions "a large strongly sulcated species (fig. 192), taken in 709 to 1,069 fathoms, which is often 3 to 5 inches long and nearly an inch in diameter."

This variety of *S. priapuloides* differs only in minor details from the form that occurs off the coast of Norway which was originally described by Koren and Danielssen (1875 and 1877). Their description has been amplified and corrected at certain points by Théel (1905), who has furnished excellent figures (especially figs. 137, 138, 150). He also gives good reasons for regarding *S. norvegicus* Koren and Danielssen as an immature form of the same species.

Roule (1907) describes a specimen of *S. priapuloides* from off Las Pilonas (No. 72 of the *Talisman* expedition) in 882 meters, and four taken in the Bay of Biscay (Golfe de Gascogne) from 800 to 1,000 meters. Roule (p. 95) recognizes that this species is probably identical with *S. norvegicus*, but employs the specific name "*priapuloides*" because the diagnosis of the latter more exactly corresponds with his specimens, and is a descriptive term rather than an inexact geographical designation. Unfortunately, in my opinion, however, he follows Levensen (1883) in making a separate genus "*Phallosoma*" to contain this species and the probably identical "*norvegicus*."

Sluiter (1900) describes *S. norvegicus* as occurring off the Azores in 1,385 meters.

The American variety was taken as far south as Charleston, South Carolina (station 2677), where it was found at a depth of only 478 fathoms, and its range extends northward at least as far as latitude  $41^{\circ}$ . The depth at which it was taken varies from 478 to 956, or, according to Verrill, 1,069 fathoms.

The chief difference between the American and the Scandinavian forms is in the number of longitudinal ridges and furrows of the trunk and of the longitudinal muscle bands, which lie beneath the furrows and correspond to them in number. The Scandinavian form is said to have 24 longitudinal muscles, whereas I have found 22 in most specimens, though others have 22 in front and 21 behind, others 23-22, and in one case 23-24. Roule (1907) finds in the specimens from the Bay of Biscay and off Las Pilonas that there are 36-38

longitudinal bands. In this respect his specimens agree more closely with *S. phalloides* Pallas of the West Indies.

The glans, as the smooth posterior end of the body is called, is not marked off from the rest of the trunk by an annular prepuce-like fold; and Théel also found, as his excellent figure 137 shows, that no fold of this sort occurs in several of the specimens from off the coast of Norway that he examined, hence it is evidently not a characteristic of any morphological importance.

The dorsal retractor muscles in the American variety spring from a single muscle band, the ventral from two, and not in each case from three or four as in the Scandinavian form.

Trunk cylindrical. As shown in Théel's excellent figure it is 110 mm. long and 16 thick; in the contracted specimens from station 2709, south of Georges Bank, it is 75 mm. long and 20 mm. thick. The introvert is distinctly marked off from the trunk, and is of much smaller diameter. It is about one-fourth as long as the trunk. The crown of tentacles consists of 8-12 primary lobes. The surface of the trunk, except at the posterior extremity, is corrugated with 21-24 longitudinal ridges and an equal number of furrows. Underlying each furrow and giving rise to it is a longitudinal muscle band. Each ridge contains a longitudinal canal, which communicates with the cœlom by numerous transverse slits in the layer of circular muscles in the interstices among the longitudinal muscle bands. The posterior extremity of the trunk is smooth, the longitudinal muscle fibers there forming a thin continuous layer rather than separate muscle bands.

No papillæ that are visible to the naked eye are found on the trunk, though very minute, dome-shaped elevations may be detected with a low power of the compound microscope, especially at the posterior extremity. The introvert, except immediately behind the tentacles, is covered with prominent papillæ in the shape of rounded cones, usually slightly longer than thick, and recurved.

The anus is prominent, and lies between one-fifth and one-fourth of the length of the trunk behind the anterior end. The openings of the nephridia lie in front of the anus, about one-half of the distance between the latter and the anterior end of the trunk.

The four retractor muscles all arise from the body wall at about one-fourth of the distance behind the anterior extremity of the trunk, and slightly behind the anus. The origin of the ventral pair is slightly behind that of the dorsal. Each ventral retractor in the variety *americana* is attached to two longitudinal muscle bands; each dorsal to a single longitudinal muscle band.

The intestinal coil is held to the body wall by numerous muscle strands, and the rectum is held by a pair of strong muscles, the attachments of which are close beside those of the dorsal retractors.

A loose racemose gland (?) lies upon each of the rectal muscles. A smooth-walled sac-shaped diverticulum of the rectum is situated near its junction with the intestinal coil. A slender columellar or "spindle" muscle is present.

Genus SIPHONOSOMA Spengel, new genus.

Through the kindness of Professor Spengel I am able to make use of this hitherto unpublished<sup>1</sup> generic term, which will include not only the American species *cumanense*, but also those formerly called *Sipunculus vastus*, *arcassonensis*, *boholensis*, and others.<sup>2</sup> Professor Spengel writes that *Siphonosoma* is characterized by its integumental canals, which are not longitudinal as in *S. nudus*, but isolated blind sacs of peculiar form, and which in their construction and arrangement present highly characteristic differences; also by the course of the ventral nerve cord, which is closely applied to the skin throughout the whole introvert, and in its most anterior part is attached to it by a short median mesentery. In the extreme anterior end of this mesentery lies a fine canal opening at the base of the tentacles that runs to the anterior end of the nerve cord, within the substance of which it enters a vesicle that appears to contain a concretion. This organ evidently represents a statocyst provided with a long canal. It occurs also in *Physcosoma*, but not in *Phascolosoma*, so far as investigated. The ciliated nuchal organ is well developed, but the cerebral tube is represented only by a shallow pit. "Other characters are the existence of a thick glandular epithelium in the wall of the rectum, the mode of attachment of the alimentary canal not by numerous threads, but by a few constant 'fixing muscles' as described, for instance, by Selenka in *S. cumanense*, the semilunar form of the nephrostomes, the arrangement of the numerous tentacles, the absence of triangular scale-like papillæ in the anterior part of the introvert, and others."

*Type species*.—*Siphonosoma australe* (Keferstein).

SIPHONOSOMA CUMANENSE (Keferstein) and var. VITREA (Selenka and Bülow).

*Phascolosoma cumanense* KEFERSTEIN, 1866.

*Sipunculus cumanensis* SELENKA, DE MAN, and BÜLOW, 1883.

In the U. S. National Museum there are eight specimens of the type form from Oyster Bay, Florida, taken among "coon oysters," and three of the variety *vitrea* from Key West, from sand along shore.

This species (pl. 60, fig. 14), originally described by Keferstein (1866) as *Phascolosoma cumanense*, in some respects is an intermediate type between that genus and *Sipunculus*. Its slender, separate tentacles are distinctly like those of *Phascolosoma*, and not like those of

<sup>1</sup> A preliminary account of this new genus and of its relations to *Sipunculus* by Professor Spengel was received while the present paper was in press. See LIST OF REFERENCES: Spengel (1912).

<sup>2</sup> Complete list of the species: *australe*, *cumanense*, *vastum*, *boholense*, *edule* Sluiter (not Pallas), *arcassonense*, *amamiense*, *bonhourci*, *rotumanum*, *funafuti*.

*Sipunculus*. On the other hand, its integument and muscles are more like those of *Sipunculus*, though as pointed out to me by Professor Spengel, its integumental canals are isolated blind sacs of peculiar form, not longitudinal vessels as in *Sipunculus nudus*.

*S. cumanense* is remarkable for the presence of transverse folds of peritoneum that cross the cœlom at regular intervals like the dissepiments of an annelid. In view of this interesting fact, which at least suggests metameric segmentation, and its somewhat generalized structure which combines characteristic features of two genera, a knowledge of its embryology is much to be desired. Its spherical eggs are exceedingly transparent, and this species therefore probably would be very favorable for observations upon the living embryo. I am informed by Professor Spengel that transverse folds of peritoneum like these are not found in the nearest allies of this species, namely, *Siphonosoma vastum*, *arcassonense*, and *boholense*.

The trunk is slender and cylindrical; the introvert about one-fifth to one-third the length of the trunk. The largest specimen from Oyster Bay measures: Trunk 19 cm., introvert 4.5 cm. (well expanded). The specimens are of grayish-brown color, and the body wall is more or less translucent, the typical form (those from Oyster Bay) being *Synapta*-like in appearance, whereas those from Key West identified as the variety *vitrea* have a more gelatinous, translucent appearance. A narrow zone upon the base of the introvert is of a lighter gray, and is covered with epidermal organs of two sizes, the larger ones being placed at somewhat regular intervals, with the smaller irregularly interspersed. The larger have the form of flat circular or elliptical papillæ with a pore or two at the center. The core of the smaller organs rises slightly above the general surface as an exceedingly minute, slender, pointed papilla. The latter are probably sensory, the former glandular or both glandular and sensory. Epidermal organs are also visible with a lens at the posterior extremity of the body. Elsewhere they are extremely minute; 20–21 longitudinal muscle bands are distinctly visible through the body wall, the surface of which is corrugated with furrows corresponding to the muscle bands and with intervening parallel ridges. The longitudinal muscle bands run to the extreme posterior end of the body. The cuticula of the introvert upon contraction is thrown up into narrow plate-like folds, but no hooks are present. There are numerous long, slender tentacles, which are entirely distinct from one another and have the usual longitudinal groove along the oral surface. The nephridiopores are slightly in front of the anus.

The four short retractors arise from the body wall in nearly the same zone, the attachments of the dorsal in some specimens being very slightly in front of those of the ventral. The two ventral retractors are attached to the second and third longitudinal muscle

bands, the dorsal to the eighth and ninth, or to the eighth alone. The dorsal retractor of each side is united to the ventral in front, and the esophagus is attached by a peritoneal membrane to the dorsal edge of this united muscle for a distance equal to about half the length of the muscle. The two lateral muscles thus formed by the union of a dorsal and a ventral of each side are quite separate from each other, though they tend to unite in front where each is attached to the esophagus. This species resembles *Sipunculus*, rather than *Phascolosoma*, as regards the position of the esophageal connectives with reference to the retractor muscles. These connectives, as they run dorsad toward the supra-esophageal ganglion, are surrounded by the outer ends of the retractors as in *Sipunculus*, instead of surrounding them as in *Phascolosoma*. The proximal half of each of the two long, slender, brown nephridia is held to the body wall by a fold of peritoneum. Selenka (1883) and Keferstein (1866), however, both describe the nephridia as short, attached, as Selenka found, only by the anterior half. The nephridiopore lies between longitudinal muscles 3 and 4. The dorsal blood vessel (contractile tube) which extends the length of the esophagus, is covered with long, slender evaginations which give it a tufted appearance.

The long intestinal coil consisting of 12-50 turns extends backward to the posterior end of the cœlom, where a long columellar muscle holds it to the body wall. This muscle branches radially and repeatedly near its posterior end, and forms a tree-shaped attachment to the body wall. The intestinal coil is held in position along its entire course, from the base of the ventral retractors backward, by numerous transverse sheets of peritoneum arranged at regular intervals like the dissepiments of an annelid. These sheets are attached laterally, but not dorsally, to the body wall at the right and left of the intestine, and stretch across the cœlom vertically. They are not attached, as far as I can discover, to the intestinal coil. Four muscle strands attach the rectum to the body wall, namely, (1) the anterior end of the columellar muscle, which is attached to the body wall in front of the anus and extends backward through the entire length of the intestinal coil, (2) two pairs of branches of the columellar muscle, one pair of which is attached to the body wall in front of the right-dorsal retractors, the other immediately behind or between the attachments of the ventral pair to the body wall. The anal end of the rectum, also, in the variety *vitrea*, is held closely to the body wall by numerous folds of peritoneum and fine fibers extending over 10 or 12 longitudinal muscle bands. A prominent cæcum is situated on the left side of the posterior end (beginning) of the rectum.

The body wall in the small specimens from Key West is more translucent than in the larger individuals from Oyster Bay, Florida, so that I have identified the former as of the variety *vitrea* Selenka

and Bülow. The length of the trunk in the largest of these specimens is about 85 mm., diameter 6 mm.; the length of the smallest 52 mm., with an introvert of 12 mm. The trunk of another is 58 mm. long. It is probable that the differences between the two "varieties" is due to the direct action of surrounding conditions and not to inheritance.

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## EXPLANATION OF PLATES.

## PLATE 58.

- FIG. 1. *Phascolosoma margaritaceum* (Sars). x 2.  
 2. *Phascolosoma cylindratum* Keferstein. x 2.  
 3. *Phascolosoma procerum* Mœbius. Nat. size.  
 4. *Phascolosoma eremita* (Sars). x 6.  
 5. *Phascolosoma verrillii* Gerould. x 2 $\frac{3}{4}$ .

## PLATE 59.

- FIG. 6. *Phascolosoma cinctum*, new species. x 13 $\frac{1}{4}$ .  
 7. *Phascolosoma verrillii* Gerould. x 24 $\frac{1}{2}$ . Drawn from a live young specimen, showing the peculiar characteristic of the species under adverse conditions of partially sloughing the cuticula at the extremity of the introvert. Length of the individual expanded, 7-8 mm.; and 5 mm. in ordinary contraction. Color, light brown; cœlomic corpuscles purple by transmitted light; *oc.*, pigmented eye.  
 8. Dissection of *Phascolosoma procerum* Mœbius. x 2. *go*, reproductive organs; *neph.*, nephridium; *n. v.*, ventral nerve cord; *oe.*, esophagus; *tb.*, Polian tube.  
 9. *Dendrostoma alutaceum* Grube. x 3.

## PLATE 60.

- FIG. 10. Tube inhabited by *Phascolion strombi* (Montagu). x 2. From station 210, off Cape Ann.  
 11. Papilla from base of introvert of *Phascolion strombi*. x 385.  
 12. Head and tentacles of *Phascolion strombi*. x 30 $\frac{3}{4}$ .  
 13. Surface view of *Phascolion strombi* var. *lævis*. x 8.  
 14. *Siphonosoma cumanense* (Keferstein), from Florida. Nat. size.



PLATE 61.

- FIG. 15. Head of *Phycosoma capitatum*. x 46.  
16. Surface view of *Phycosoma capitatum*. x  $6\frac{1}{2}$ . From station 2029.  
17. Surface view of *Aspidosiphon parvulus*. x  $17\frac{1}{2}$ .

PLATE 62:

- FIG. 18. *Phycosoma varians* Keferstein. x 2.  
19. *Phycosoma antillarum* Grube and Örsted. A large contracted specimen.  
x 2.  
20. *Phycosoma antillarum*, an expanded specimen. x 2.  
21. *Phycosoma capitatum*, new species. x  $2\frac{3}{4}$ .  
22. *Aspidosiphon speciosus*, new species. x 2.